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THE
WEALTH OF INDIA

A Dictionary of Indian Raw Materials
and Industrial Products

INDUSTRIAL PRODUCTS
PART I

A - Bu

DELHI
1948

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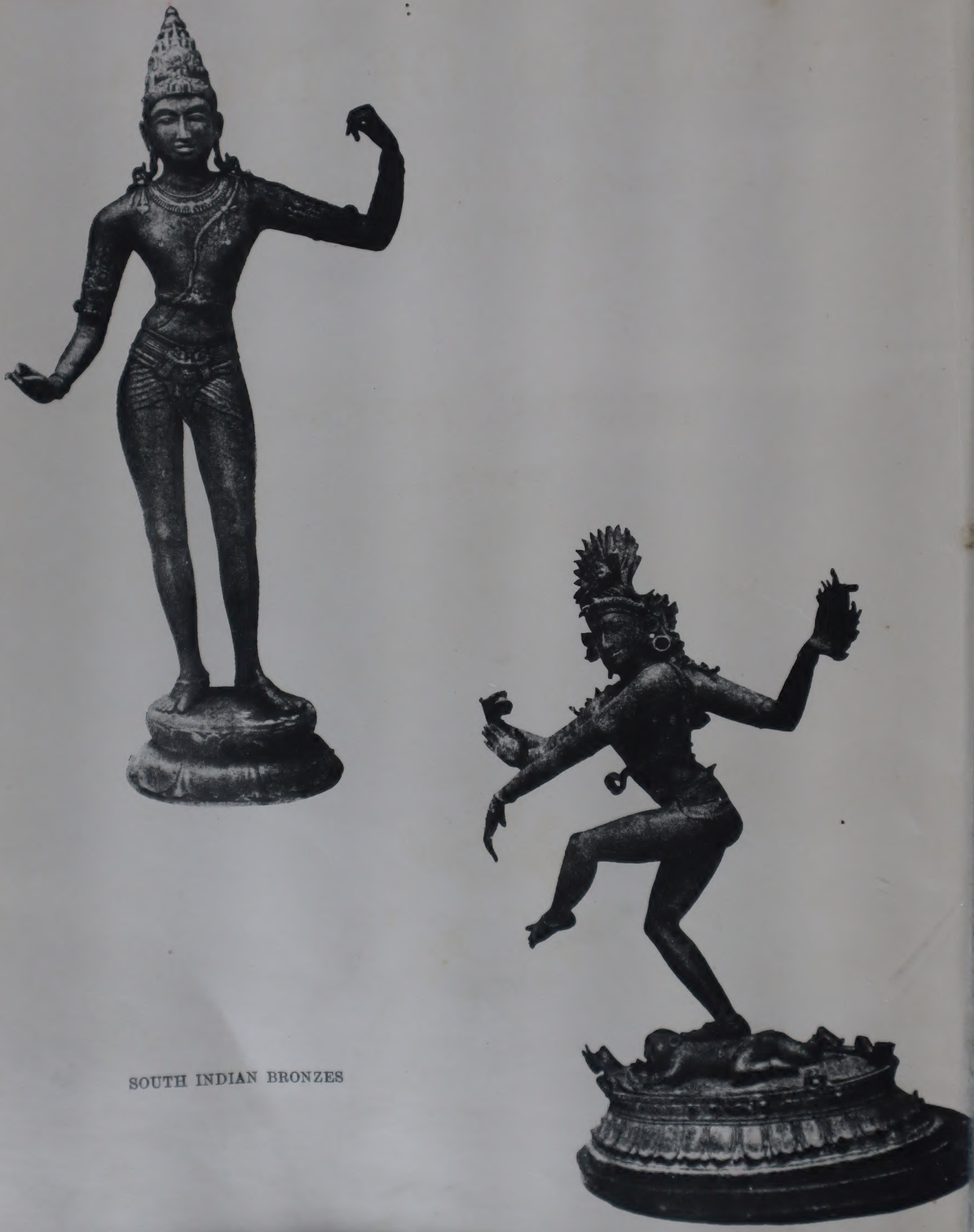

SOUTH INDIAN BRONZES

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A Dictionary of Indian Raw Materials and Industrial Products

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PART I

A - Bu

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH · INDIA ·

DELHI
1948

Published by
The Council of Scientific &
Industrial Research,
20, Pusa Road,

New Delhi.

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INTRODUCTION

When considering the scheme for the compilation of a Dictionary of Raw Materials similar to Watt's publications, the members of the Advisory Board appointed by the Governing Body of the Council of Scientific and Industrial Research, felt that the new compilation should have a different orientation. Watt's Dictionary of Economic Products of India and the Commercial Products of India were compiled almost entirely with reference to the economic exploitation of Indian materials by foreign industrial and commercial interests. The Board opined that the primary purpose of the new work should be to secure fuller utilization of Indian materials by Indian industrial and commercial interests, and therefore that it should also include Indian industrial products.

The Editorial Committee of the Board, while considering the details of the scheme, directed that articles on Indian industries and industrial products should form a separate volume. This was felt necessary because of two reasons : (*a*) the obvious difference between the treatment of these subjects and raw materials, and (*b*) the necessity for more frequent revision of the volume, owing to the rapidly changing industrial picture of the country.

Further, the Committee also issued the following directions for the treatment of subjects to be included in this volume :—

1. The articles should give a critical account of published data regarding industries and no new surveys should be undertaken.

2. In the case of manufacturing industries only methods employed in the country should be described. Important processes followed elsewhere should be indicated, with suitable references to literature.

3. Imported raw materials and processed articles should be included under the manufactures or industries, in which they are employed. Their sources and the manner in which they are used should be indicated.

4. The Dictionary should also include Cottage Industries.

The selection of materials to be included in this volume presented various difficulties. Several Directories and Reports of Industrial Surveys were consulted, and the final list has been based on the Alphabetical index of the commodities that enter into the foreign Sea-borne Trade of British India (1939), Brady's Materials Handbook, and the Raw Materials Guide (Ministry of Supply, London).

In the articles on these subjects an attempt is made to trace the development of the various industries in India, and to describe their present position. The principal raw materials of each industry, their sources and availability, are indicated. This is followed by a description of the manufacturing processes employed in India. Where available, statistical data, drawn from official sources, are included in the trade survey.

The reader will find certain unevenness in the different sections. This is due to the present transitional stage in India's industrial development, the absence of much published information on many of the industries, and of statistical data, and the reluctance on the part of certain industries to give information. But grateful acknowledgment is made to the co-operation extended to the Chief Editor by several industrialists, experts and Government Departments, and by his colleagues.

The present publication is the first part of this volume. Suggestions for improvement, and additional information will be made use of in the subsequent parts and editions.

B. L. MANJUNATH,
Chief Editor.

20, Pusa Road, New Delhi.

TO THE READER

1. Books, journals and periodicals referred to are listed on p. x & xi. The abbreviated titles generally conform to those adopted in the World List of Scientific Periodicals (1934). In the case of books, the author's name is followed by the page reference. When two or more books by the same author are referred to, the year of publication is given immediately after the author's name. After the title of a journal, the year of issue, volume No. (clarendon type), number of part, if any, and page No. are listed successively.

2. A careful selection of references has been made and these are usually inserted at the most convenient points in the article, though they have been made use of in a more general manner.

3. In general, literature up to the end of 1945 has been consulted. In the case of some articles, information published later, has been added during the proof stage.

4. Statistical information has been taken from official sources, such as the publications of the Department of Commercial Intelligence, and the Central Marketing Department.

5. A list of the less familiar abbreviations and symbols is added for the benefit of the general reader. The others employed are as per the Dictionary of Abbreviations by C. C. Matthews (1947).

6. Temperatures, unless otherwise specified, always refer to the Centigrade scale.

LIST OF CONTRIBUTORS

Messrs. Agrico Factory, Jamshedpur	Agricultural Implements.
Alembic Chemical Works Co. Ltd., Baroda	Potassium Carbonate.
Baros, Jan, Bata Shoe Co., Batanagar	An Outline of the History of Shoe-makers in India.
Cooper, Allen & Co., Cawnpore	Foot-wear.
Goswami, M. N., University College of Science and Technology, Calcutta	Stearic acid and stearin.
Indian Oxygen & Acetylene Co. Ltd., Cawnpore	Acetylene.
Joglekar, G. D., Physics Section of the Council of Scientific and Industrial Res. Laboratories, Delhi	Storage Batteries, and Dry cells.
Kenneth Hall, formerly General Manager, Aluminium Production Co. (India) Ltd., Calcutta	Aluminium.
Mettur Chemical & Industrial Corpn., Ltd., Mettur	Barium chloride, and Barium carbonate.
Nagaraja Rao, A., General Manager and Chemical Adviser, Eastern Chemical Co. (India), Bombay	Hydrochloric, Nitric, and Sulphuric acids.
Ditto	Sodium carbonate, and bicarbonate, and caustic soda.
Parekh, M. D., C/o The Managing Agents, National Rayons Ltd., Fort, Bombay	Oxalic acid.
Pioneer Magnesia Works, Chartered Bank Buildings, Fort, Bombay	Bromine.
Rangaswami, V. N., Burmah Shell Co., New Delhi	Bitumen.
Roy, S. K., Bengal Belting Works Ltd., Calcutta	Belting.
Rudrappa, S. C., Proprietor, Shroff Channabasappa & Sons, Bangalore City	Agarbattis.

LIST OF PLATES

Plate No.	Description	Acknowledgment
I	(Frontispiece) South Indian bronzes	Supt., Govt. Museum, Madras.
II	1. Fermentation tanks 2. Rectifying Column 3. Dehydrating Column	Messrs. Central Distilleries and Chemical Works, Meerut.
III	1. Electrolytic Reduction Cells 2. Casting Aluminium into Ingots 3. Aluminium Rolling Mills	Messrs. Indian Aluminium Co., Calcutta.
IV	1. Aerial view of Synthetic Ammonia Factory 2. Converter in erection 3. Converter Assembly	Messrs. Fertilisers & Chemicals, Travancore, Alwaye.
V	1, 2 & 3. Older types of Bidriware	The Prince of Wales' Museum, Bombay.
	4, 5 & 6. Modern Bidriware	Govt. Cottage Industr. Sales Depot, Hyderabad (Dn.).
	7. Lucknow Bidriware	Mrs. Lalitha Verman, New Delhi.
VI	1. Indigenous footwear	Mr. M. Jan Baros, Bata Shoe Co.
	2, 3 & 4. Delhi *zari jootis*	Messrs. Hamdard Chappal Co., and Baluja Shoe Co., Delhi.
VII	1. Water-pot from Benares 2. Muradabad *lota* 3. *Aftaba* from Muradabad 4. *Surahi* from Jaipur	Baroda State Museum & Picture Gallery, Baroda.
VIII	Jaipur Artware : 1. Plate, *Chikan* work 2. Plate, *Marori* work 3. Cigarette case 4. Flower vase	Messrs. Kotai Art Works, New Delhi.

BOOKS

Author	Year	Title
Armstrong, E. F. and Miall, L. M.	1943	Raw Materials from the Sea.
Badger, W. L. and Baker, E. M.	1941	Inorganic Chemical Technology.
Bruttini, A.	1923	Uses of Waste Materials.
Hilditch, T. P.	1943	The Industrial Chemistry of the Fats and Waxes.
Jacobs, M. B.	1944	The Chemistry and Technology of Food and Food Products. 2 Vols.
Jamieson, G. S.	1943	Vegetable Fats and Oils.
Kingzett, C. T.	1945	Kingzett's Chemical Encyclopaedia. 7th Ed.
Loesecke, H. W. (von.)	1942	Outlines of Food Technology.
McCance, R. A. and Widdowson, E. M.	1946	The Chemical Composition of Foods.
Riegel, E. R.	1942	Industrial Chemistry.
Rogers, A.	1943	Industrial Chemistry. 2 Vols. 6th Ed.
Shreve, R. N.	1945	The Chemical Process Industries.
Thorpe, E.	1937—47	Dictionary of Applied Chemistry. 4th Ed. 8 Vols.
Trotter, H.	1940	Manual of Indian Forest Utilization.
Do.	1944	The Common Commercial Timbers of India.

JOURNALS AND PERIODICALS

Biochem. Res. India	Biochemical and Allied Research in India.
Bull. imp. Inst., Lond.	Bulletin of the Imperial Institute, London.
Bull. Indian Industr. Res.	Bulletin of Indian Industrial Research.
Capital	Capital, Calcutta.
Chem. Engng.	Chemical Engineering, New York.
Chem. Engng. News	Chemical and Engineering News.
Chem. metall. Engng.	Chemical and Metallurgical Engineering, New York.
Chem. Tr. J.	Chemical Trade Journal and Chemical Engineer, Manchester.
Dep. Agric., U. P., Bull.	Department of Agriculture, U. P., Bulletin.
Dep. Industr., Bengal, Bull.	Department of Industries, Bengal, Bulletin.
Dep. Industr., Bombay, Bull.	Department of Industries, Bombay, Bulletin.
East. Economist	Eastern Economist, Delhi.
For. Comm. & Navig. U. S.	Foreign Commerce & Navigation of the United States.
Gaz. India	Gazette of India.
Hlth. Bull.	Health Bulletin.
Imp. Coun. Agric. Res., Misc. Bull.	Imperial Council of Agricultural Research, Miscellaneous Bulletin.
Indian Chem. Mfrs. Ass., News Sheet	Indian Chemical Manufacturers' Association, News Sheet, Calcutta.
Indian Customs Tariff	Indian Customs Tariff.
Indian For.	Indian Forester.
Indian Fmg.	Indian Farming.
Indian For. Bull., New Series	Indian Forest Bulletin, New Series.
Indian For. Leafl.	Indian Forest Leaflet.
Indian For. Rec.	Indian Forest Records.
Indian For. Rec., New Series, Util.	Indian Forest Records, New Series, Utilization.
Indian Sugar	Indian Sugar, Cawnpore.
Indian Tr. J.	Indian Trade Journal.
Indian Tr. Bull.	Indian Trade Bulletin.
Industr. Chem.	Industrial Chemist.
Industr. Engng. Chem.	Industrial and Engineering Chemistry.
Int. Sugar J.	International Sugar Journal.
J. chem. Educ.	Journal of Chemical Education, Easton Pa.
J. Indian chem. Soc., Industr. & News., Edn.	Journal of the Indian Chemical Society, Industrial and News Edition.
J. Indian Inst. Sci.	Journal of the Indian Institute of Science.
J. sci. industr. Res.	Journal of Scientific & Industrial Research.
Kew Bull.	Bulletin of Miscellaneous Information, Royal Botanic Gardens, Kew, London.
Madras agric. J.	Madras Agricultural Journal.
Mem. geol. Surv. India	Memoirs of the Geological Survey of India.
Miner. Yearbook	Mineral Yearbook, Washington.
Mon. Statist. Production sel. Industr. India	Monthly Statistics of the Production of Certain Selected Industries of India.
Plastics	Plastics, London.
Proc. nat. Inst. Sci. India	Proceedings of the National Institute of Sciences, India.
Quart. J. geol. Soc. India	Quarterly Journal of the Geological, Mining and Metallurgical Society of India.
Rec. geol. Surv. India	Records of the Geological Survey of India.
Rec. geol. Surv. India, Bull. Econ. Miner.	Records of the Geological Survey of India, Bulletin, Economic Minerals.
Sci. & Cult.	Science & Culture.
Statist. Abstr. Br. India	Statistical Abstract for British India.
Tr. U. K.	Annual Statement of the Trade of the United Kingdom with British countries and Foreign countries. Vol. III.
Trans. Min. geol. metall. Inst. India	Transactions of the Mining, Geological and Metallurgical Institute of India.

ABBREVIATIONS AND SYMBOLS

atm.	Atmosphere.
Be.	Baume.
b.p.	Boiling point.
B. P.	British Pharmacopoeia (1932).
B. S. S.	British Standard Specification.
B. Th. U.	British thermal unit.
cal.	Calorie ; calorific.
conc.	Concentrated ; Concentration.
C. P.	George Watt : Commercial Products of India (1908).
d	Density.
dil.	Dilute.
e. m. f.	Electromotive force.
g.	Gram.
G. I.	Galvanised iron.
G. P.	General purpose.
H.	Hardness.
iod. val.	Iodine value.
kw.-hr.	Kilowatt hour.
md.	Maund (82 lb.).
m. p.	Melting point.
M. S.	Mild Steel.
n. a.	Not available.
N. T. P.	Normal temperature and pressure.
o. p.	Over proof.
p_c	Critical pressure.
pdr.	Pounder.
p_c	Hydrogen ion concentration.
qty.	Quantity.
R. M. val.	Reichert Meissl value.
Specif.	Specification.
S. W. G.	Standard wire gauge.
t_c	Critical temperature.
T. N. T.	Trinitrotoluene.
v. p.	Vapour pressure.

THE WEALTH OF INDIA

INDUSTRIES

PART I

ABRASIVES

Abrasives include a wide range of materials extensively used in almost every branch of industry for cutting, drilling, grinding and polishing. The materials employed are required to be hard, tough and sharp.

The following are the principal natural abrasives and the forms in which they are used (Sahni, *Rec. geol. Surv. India*, 1942, **76**, *Bull. Econ. Min.*, No. 12) :

Natural Abrasives	H (Moh's scale)	Forms used
Diamond ...	10	Crystals (bort).
Corundum ...	9	Grinding wheels.
Emery ...	9-8	Loose grains for polishing gems, and grinding glass. Abrasive cloth and paper, and grinding wheels.
Garnet ...	8	Do.
Quartz, quartzite and sand	7	Powder for grinding glass, and for sand-paper.
Flint ...	...	Abrasive cloth and paper.
Sandstones and granite	...	Millstones, grindstones and whetstones.
Talc ...	1	Powder for abrasive and polishing compositions.
Felspar ...	6	Do.
Other siliceous abrasives (diatomite, tripolite, pumice, rottenstone and siliceous clays)	...	Do.

The first four are natural high grade abrasives. On account of the high cost of diamond only inferior varieties (bort), and diamond dust are available for abrasive purposes. They are used in drilling rocks, and in cutting glass. Emery is extensively employed for the manufacture of different grades of abrasive cloths and papers, and loose grains are used for polishing gems, and grinding glass. Emery is also bonded into wheels for cutting metals. White or grey corundum is used for similar purposes. Fine grains of corundum are employed for polishing gems, and for grinding and bevelling glass. Abrasive cloths, papers and discs are manufactured from graded garnet sands. These are used for polishing glass, wood, leather, etc.

The production of diamonds in India is very small. Emery suitable for abrasive purposes has not been found in the country, and during the last War ('39-45) arrangements were made for the import of 300 tons of emery from Turkey. Good grade corundum (rock and loose grains) is found in Assam, Rewa, Madras (Salem) and Mysore. It was mined and exported to the U. K. during the First World War, but there is now considerable difficulty in obtaining adequate supplies. Production is mostly sporadic, and the material collected is not properly graded or marketed. Most of the garnets produced in India are used as gem stones. Garnet sands suitable for abrasive purposes occur in Bihar and in the Tinnevelly dist., Madras.

The natural siliceous abrasives are not so important and several of them are found in adequate quantities in India. Quartz and quartz sands are used for sand-blasting, cutting, grinding and polishing stones, marble and glass. Flint is employed as a substitute for emery in the preparation of abrasive cloths and papers, but in India, it is not used to any extent. Millstones, grindstones and whetstones are prepared from suitable sandstones and fine-grained granites. High grade talc is fairly widely distributed and may be converted into talc powder for use in polishing compositions. Felspar, a waste product from mica mines, could be ground to powder and used for scouring and polishing compositions. In India, diatomite, tripolite, pumice and rottenstone, which are used in various abrasive powders and metal polishes, are not found in workable quantities.

In industrially advanced countries natural high grade abrasives are being displaced by artificial abrasives, chiefly due to their greater uniformity in shape and hardness. The most important of these are fused alumina (Alundum, H. 9.2-9.6); silicon carbide (Carborundum, H. 9.5-9.75) and boron carbide (Norbides). In hardness boron carbide is intermediate between silicon carbide and diamond. These synthetic grains are used for the production of grinding wheels and stones, coated abrasives, grains, powders, etc.

Synthetic abrasive grains are manufactured in the electric furnace. For preparing alundum, high grade calcined bauxite is mixed with iron filings and coke and heated in an arc furnace for 24 hours. The ingot of fused alumina is separated from ferrosilicon, crushed and graded. In the manufacture of carborundum pure quartz sand mixed with high grade coke and powdered salt is heated in an electric furnace. Norbide is similarly made from boric acid and coke, and is now very prominent in the abrasives industry.

The production and use of abrasives have not developed to any considerable extent in India. There are four large firms manufacturing coated abrasives: sand-paper, emery paper and cloth, and two firms producing grinding wheels and discs. Besides, the production of coated abrasives is also a well-established cottage industry.

The U. S. A. is the chief supplier of synthetic abrasive grains and the import duty is 30 per cent. *ad valorem.*

EXPORTS OF ABRASIVES FROM THE U. S. A. TO INDIA*

(Qty. in 1000 lb. and val. in $. 1000)

Year	Grindstones and other natural abrasives		Synthetic abrasive grains	
	Qty.	Val.	Qty.	Val.
'40	790	19	169	24
'41	595	31	183	16
'42	n. a.	n. a.	n. a.	n. a.
'43	221	15	221	14
'44	177	7	653	58

* *For. Comm. & Navig. U. S.* The U. S. A. also supplied small quantities of emery powder (22,000 lb. in '43 & '44), and steel wool for abrasive purposes (av. annual imports, 6,930 lb. during '40-44).

COATED ABRASIVES

Coated abrasives are: sand, glass or flint paper and cloth; emery paper and cloth; garnet paper and cloth; aluminium oxide paper, cloth and combination; silicon carbide paper, cloth and combination; water-proof abrasive paper, etc. These are sold in sheets, rolls, discs, belts, tapes or coils. The larger consuming industries in India are the engineering and automobile works, leather factories, railways, and furniture makers. They are extensively used for abrading, polishing and sharpening of all types of materials.

The first attempts at large-scale manufacture of coated abrasives were made in '29 by the Strawboard Manufacturing Co. at Saharanpur. In '38, Messrs. Krishanlal Thirani & Co. (Calcutta) went into production, and now Messrs. National Sand

Paper Mills Ltd. (Rawalpindi), and Ajax Products Ltd. (Madras), who started production during the last War, are the principal producers of coated abrasives. In addition, a few small concerns and the cottage industry account for about 20 per cent. of total production capacity.

The principal raw materials of this industry are natural abrasive minerals such as quartz, garnet, corundum and emery ; synthetic abrasive minerals such as silicon carbide and aluminium oxide grains; backing paper (kraft), cloth and vulcanized fibre ; and hide glue as binding material.

Emery is imported from Turkey, and silicon carbide and aluminium oxide grains, kraft paper and vulcanized fibre, from the U. S. A. During the Second World War, indigenous corundum was used as a substitute. But supplies of corundum were inadequate, and its price ranged between Rs. 450 and Rs. 600 per ton as against Rs. 390 per ton of imported emery. Waste glass and glass pieces are used for making glass paper, also called sand-paper.

In the manufacture of coated abrasives, abrasive materials which are in the form of big lumps (9″×12″) are first reduced to smaller pieces (1″×1″) by a preliminary crushing, and later reduced to finer sizes by means of roll crushers and graded. The mill-roll of paper on which the maker's name and trade mark are printed, is passed through a vacuum drum between calender rolls in the coating machine and given a coating of the hide-glue. The coated surface is next passed under the spreader below a hopper which feeds the abrasive grains. It is then given a second coating of glue in a sizing machine in order to fix the grains on to the backing, and dried and rolled into a jumbo, *i.e.*, the finished coated abrasive roll. After sufficient ageing, it is cut to required size and marketed (Rep. Indian Tariff Bd. Coated Abrasives Industry, 1946).

The rated capacity of indigenous producers, on the basis of two shifts a day, is estimated to be 200,000 reams per annum. But owing to shortage of raw materials, production has been only 50 per cent. of rated capacity. The maximum output was reached in '43 when production was 84,000-104,000 reams, valued at Rs. 21 lakhs.

The value of abrasives, distributed industry-wise in '43 was Rs. 9 lakhs for Ordnance Factories and Defence Service requirements, and Rs. 18 lakhs for civilian use. In terms of quantity consumed, this represented 104,000-135,000 reams of abrasives.

In India, sand flint paper, and corundum or emery cloth are in largest demand, and these are the principal coated abrasives manufactured. The fair selling price per ream of Indian sand/flint paper in '46 (July-Dec.)has been estimated at Rs.21-2, and the average landed cost of imported paper with existing duty, at Rs. 29-2. In the case of carborundum or emery cloth made in India, the fair selling price was estimated at Rs. 65-11, while the landed cost of better grades of imported carborundum or emery cloth was Rs. 62-6 and of cheaper grades, Rs. 43-15. Indian prices are expected to come down if production is increased. With the existing revenue duties *ad valorem* (30 per cent. on emery cloth ; 36 per cent. standard rate on abrasive papers ; and 24 per cent. preferential rate on imports from U. K.), indigenous manufactures can compete with imported products. Recently the Govt. of India converted these duties into protective duties *ad valorem* up to 31st Mar. '49.

Before '39, India was importing coated abrasives mainly from the U. K., the U. S. A., Italy and Japan. During the War U. K. was the principal supplier.

EXPORT OF COATED ABRASIVES FROM U. K. TO INDIA*

(Qty. in 1000 cwt., and val. in £1000)

	Emery cloth and papers		Glass and Sand cloth and papers		Other abrasive cloths and papers	
	Cwt.	Val.	Cwt.	Val.	Cwt.	Val.
'35-39 (annual av.)	2.5	12.8	5.5	13.7		
'40	4.6	21.5	6.6	23.1	0.35	3.1
'41	4.0	24.7	7.1	30.6	0.41	4.6
'42	3.7	25.6	3.1	15,5	0.30	4.3
'43	4.2	17.9	3.0	14.6	0.58	9.2
'44	4.8	35.7	5.0	23.7	0.80	13.1
'45	2.6	19.7	0.7	4.0	0.28	4.5

* *Tr. U. K.*, III.

GRINDING WHEELS

Grinding wheels are required for grinding iron and steel, agate, vitrified bricks, glass, granite, leather, porcelain, slate, etc., and come into the market in different sizes, shapes and specifications. The variety of work in which grinding wheels are used comprises tool and cutter sharpening, cylindrical grinding, roll grinding, general and surface grinding and the grinding of cereals into starch, flour, etc.

In India grinding wheels are at present manufactured by two firms : Messrs. Grindwell Ltd. (Bombay), and Kata Grinding Wheel Works (Amritsar). Messrs. Grindwell Ltd. came into existence just before the outbreak of the Second World War. Their present capital investment is about Rs. 3.5 lakhs, and they have a rated capacity of 250 tons of wheels per annum. The Kata Works at Amritsar have a rated capacity of 60 tons per annum, which could be doubled.

The principal raw materials employed in grinding wheel manufacture are the imported synthetic abrasives, silicon carbide and fused alumina, which account for over 90 per cent. of grinding wheels made in India. The Kata Works use Rewa corundum. Compared with imported wheels, the efficiency of their wheels was about 75 per cent. Other raw materials, *viz.*, fire clay, pipe clay, magnesite, plaster of Paris and silicate of soda, are obtained from indigenous sources.

Indian manufactures are chiefly vitrified grinding wheels. In the manufacture of these, an intimate mixture of abrasive grains and clay bonding with the requisite amount of moisture, is prepared. The ratio of abrasive to the bonding material determines the hardness and density of the wheel. The mixture is put into oversize moulds and pressed into wheels in hydraulic or hand presses. These are dried for two days in a heated room, and then raw-dressed and given the required indentations and shapes. The last traces of moisture are eliminated by leaving the raw wheels in another drying room for 6-30 days according to size. Finally, they are loaded into kilns of 6ft.-18ft. diameter, and fired at several points by coal, oil or gas. The highest temperature is reached gradually in 8 full days, and similarly, the cooling of the kilns is effected gradually.

The wheels are finally dressed to dimensions on specially designed machines. Wheels over 6″ in diameter receive a speed test. The vitrified type of wheels have a working speed ranging from 5,000-6,000 surface feet per min. and the test speed is approximately 9,000 surface feet per min. Silicon, shellac, rubber and bakelite bonds are also used for special purposes, the last two being mainly used for speed exceeding 9,000 surface feet per min.

There are innumerable types of wheels and segments of different grits and grades produced by the same process. But the standard types which are produced and sold in large numbers in India are of sizes

10″×1″ (wt., 6.8 lb.) ; 12″×1″ (wt., 9.7 lb.) ; 12″×2″ (wt., 19.0 lb.). The quality of Indian grinding wheels gave no room for complaint during the War, and the Railway Bd. has recently included the grinding wheels made by Grindwell Ltd. permanently on the approved list.

INDIAN PRODUCTION OF GRINDING WHEELS

Year	Tons	Rs.
'43	111	10,62,643
'44	159	12,32,000
'45	187	7,49.833

Messrs. Grindwell Ltd. produced over 90 per cent. of the total Indian production and were the principal suppliers to the Govt. and the Railways (in '43, 76,000 lb., in '44, 200,000 lb., and in '45, 276,000 lb.). It is estimated that 40 per cent. of the Indian demand comes from the railways and ordnance factories and the rest from industry.

The cost of production of Messrs. Grindwell Ltd., in '45, was Rs. 2-12 per lb., and it is expected to come down to about Rs. 2-4 during '47-49. But the landed cost, ex duty, of imported grinding wheels is less than half this figure (Rep. Indian Tariff Bd. Grinding Wheels Industry, 1946). In order to encourage indigenous manufacture, the Govt. of India placed a temporary ban up to the end of '48 on the import of grinding wheels similar to those manufactured in India, and imposed a duty of 50 per cent. on other grades of grinding wheels not locally made, and removed the duty on imported raw materials. After '48 it is proposed to impose a 50 per cent. duty on all types and grades of grinding wheels.

Before the War, practically the entire Indian demand for grinding wheels was met by imports from the U. K.

EXPORTS OF GRINDING WHEELS ETC. FROM THE U.K. TO INDIA

(No. in 1000; qty. in 1000 cwt.; val. in £ 1000)

Year	Wheels of artificial corundum, including alundum, aloxite, etc.			Wheels of corundum			Other hard abrasives manufactured			Other manufactured abrasives ground, pulverised, refined or otherwise prepared			
										Natural		Artificial	
	No.	Qty.	Val.	No.	Qty.	Val.	No.	Qty.	Val.	Qty.	Val.	Qty.	Val.
'35-39 (annual av.)	17.4	..	8.0.	17.5	..	10.3	..	...	..	..	...	..	..
'40	31.6	2.01	19.5	52.1	3.4	26.8	39.5	2.5	22.9	5.1	6.9	0.6	3.7
'41	54.2	3.0	29.6	23.0	1.7	15.0	53.2	2.8	25.1	4.3	6.1	1.1	6.2
'42	31.6	1.8	16.9	30.9	2.6	20.9	60.4	3.6	31.9	1.6	2.8	0.7	4.6
'43	7.2	0.3	3.1	27.5	1.8	15.0	74.6	4.5	41.3	2.5	5.0	1.2	5.5
'44	18.3	1.5	12.4	66.0	5.5	45.3	127.3	7.9	69.7	5.7	15.5	2.1	14.0
'45	9.4	0.6	5.1	43.4	2.6	23.1	48.0	3.2	28.9	5.1	13.7	1.6	9.9

• *Tr. U. K.*, III.

ACETONE

Acetone is a clear colourless mobile liquid with a characteristic odour and a pungent sweetish taste (sp. gr./15°, 0.7972 ; b. p., 56.5° ; wt. per gal., 8.0 lb.). It is highly inflammable, its flash-point being −16°, and its vapours form explosive mixtures with air. It is miscible with water, alcohol, ether and chloroform. It dissolves several organic substances, especially volatile and fixed oils, resins, tannins, etc. Acetone also dissolves potassium permanganate, and when pure, it is not acted upon by it.

Acetone is present in very small amounts in normal urine, but the proportion becomes prominent in diabetes. Its presence is detected by Legal's test. A slightly alkaline solution (KOH) with sodium nitroprusside gives a red colour, which changes rapidly to yellow, and on the addition of acetic acid becomes reddish-violet and finally blue.

Acetone is a valuable industrial solvent. Its chief uses are in the manufacture of acetate rayon (4 lb. being required for 1 lb. of rayon), as a solvent for nitrocellulose in the manufacture of cordite and smokeless powders, and for the storage of acetylene (q. v.). 22 lb. of acetone are required for the manufacture of 100 lb. of cordite, and solvent recovery is about 5-7 lb. Acetone is also used in the manufacture of celluloid, varnishes, paints, and aeroplane dopes, and is employed for the extraction of fats and oils, and various drugs and perfumes.

In India, acetone is principally used in the manufacture of cordite and smokeless powder, and the civilian demand is chiefly for use in acetylene cylinders (25 tons per annum).

Acetone is one of the constituents of pyroligneous acid obtained during wood distillation (q. v.), and during its processing, it passes into crude methanol of which it forms about 15 per cent. It cannot be separated from methyl alcohol by fractional distillation, since the two form a constant boiling mixture (90 per cent. acetone, and 10 per cent. methyl alcohol) of b. p., 65.9°. Consequently, during the rectification of 'crude methanol,' the constant boiling mixture passes over first. This is also known as 'methyl acetone,' and is used as a solvent and denaturant. The technical product from the Mysore Iron Works contains 50-55 per cent. of acetone (*vide* Wood distillation), the rest consisting of methyl acetate, methyl alcohol, etc.

Acetone was formerly manufactured almost entirely from grey acetate of lime obtained from pyroligneous acid. The material contains usually 80-82 per cent. of calcium acetate and on heating decomposes thus :

$$(CH_3COO)_2Ca \rightarrow CH_3COCH_3 + CaCO_3$$

A modification of this method is the direct catalytic conversion of acetic acid to acetone.

Technical grey acetate is charged into shallow trays in a closed chamber and heated in an inert atmosphere to 450-500° for about 8 hrs. The crude acetone formed is condensed and run into storage. Crude acetone is diluted with an equal volume of water and vigorously stirred when acetone oils, consisting of higher ketones such as methyl ethyl ketone, etc., separate out and form an oily layer. The aqueous portion which holds all the acetone is subjected to fractional distillation, and fractions, which are completely miscible with water and are stable towards permanganate, are removed as the finished product. Acetone of very high purity is required for the manufacture of smokeless powder, and for the celluloid industry.

Acetone oil is graded into 'white acetone oil,' b. p., 70-130°, and 'yellow acetone oil,' b. p., 130-250°. These are also used as solvents and denaturants.

100 lb. of grey acetate yield nearly 18 lb. of acetone and 4.8 lb. of acetone oil. Acetone was being manufactured by the above process in the Cordite Factory at Aruvankadu (Nilgiris) from grey acetate obtained

from the wood distillation plant of the Mysore Iron Works at Bhadravati. During the last War ('39-45), owing to fall in supplies due to decrease in the quantity of wood distilled, and the urgent need for acetone for the production of increased quantities of cordite, a plant was erected for production of 1,000 tons of acetone annually from alcohol.

In the process developed by the British Industrial Solvents Ltd., a mixture of alcohol and superheated steam (1 :4) is passed through a series of reaction vessels at 470° containing specially chemically treated ferric oxide. The following reaction takes place :

$$2\,C_2H_5OH+H_2O \rightarrow (CH_3)_2CO+4H_2+CO_2$$

The gases containing also some unconverted alcohol pass through condensers and scrubbers, the concentration of acetone in the condensate being about 5 per cent. From this, pure acetone is obtained by rectification. The best yield is of the order of 80 per cent.

The fermentation process for the technical production of acetone was developed during the First World War by Weizmann following the earlier investigations of Fernbach (Riegel, 350 ; and *Industr. Engng. Chem.*, 1928, **20**, 1063). Under carefully controlled conditions, the organism, *Clostridium acetobutylicum*, isolated from the surface of corn and other cereals, and also found in the soil, acts on corn mash and degrades starch into butyl alcohol, acetone and ethyl alcohol (6 : 3 : 1). It has now been adapted for the fermentation of molasses. Sugar concentration is kept at 5 per cent., some nitrogen is supplied and the entire fermentation is carried under sterile conditions for about 45 hrs. The yield of mixed solvents on the basis of the sugar content of molasses is 30-33 per cent. These are separated by distillation and the constituents are separated and purified by fractional distillation (*Industr. Engng. Chem.*, 1937, **29**, 1399).

During the First World War, a plant in Canada working Weizmann's process produced about a million gallons of acetone in two years. A factory was being erected in India (at Nasik), to produce acetone from rice and *jawar* (*Sorghum vulgare*). The project was dropped when the War ended. Fowler *et al.* (*J. Indian Inst. Sci.*, 1921, **4**A, 1; 1925, **8**A, 71 and 84) have attempted to use *mahua* flowers (*Madhuca indica*) in acetone-butylic fermentation. The fermentation process using molasses is now being worked in the U. S. A. mainly for the production of butyl alcohol, and acetone is obtained as a secondary product.

Large quantities of acetone are also manufactured from propylene, a constituent of gases evolved during the cracking of petroleum. Propylene is converted into isopropyl alcohol and the latter dehydrogenated or oxidized to acetone. Acetylene forms another raw material for the production of acetone. The process of conversion is similar to the one for producing acetaldehyde except that longer time is allowed :

$$CH{\equiv}CH+H_2O \rightarrow \; CH_3CHO \rightarrow$$
$$2CH_3CHO+H_2O \rightarrow (CH_3)_2CO+CO_2+2H_2$$

The rapid expansion in the production of acetone in America by synthetic and fermentation processes has brought down the price to 5 c. per lb.

BUTYL ALCOHOL

N-Butyl alcohol obtained by the fermentation process is a colourless inflammable liquid of b. p., 115°. It is also prepared synthetically from acetaldehyde. It dissolves in water to the extent of about 10 per cent. by weight, but is freely miscible with most organic solvents. It is an excellent solvent for several gums and resins, and lacquer and agar, and is extensively used in the preparation of paints and varnishes. Butyl acetate prepared from it (b. p., 126.5°) has even better solvent properties, and is used for similar purposes.

ACETYLENE

Acetylene is a colourless inflammable gas obtained by the action of water on calcium carbide :

$$CaC_2+2H_2O \rightarrow C_2H_2+Ca(OH)_2+30.4\text{kg.-cal.}$$

When pure, it has a slightly ethereal odour, but when produced from commercial calcium carbide, it has a distinct unpleasant odour due to the presence of traces of phosphene, etc. In small quantities the gas is non-poisonous, but when present in concentrations of more than 40 per cent., it may produce asphyxiation. Acetylene dissolves in an equal volume of water. It is more soluble in organic solvents, especially in acetone. At ordinary pressure and 15°, acetone absorbs 25 times its volume of acetylene. At 12 atm., it takes up 300 volumes and at 15 atm. nearly 375 vol. This property is made use of for the storage of acetylene in the dissolved state.

Acetylene is an endothermic compound, its heat of formation being nearly 50 kg.-cal. g. mol. Both the gas (t_c, 37° ; p_c, 62 atm.) and the liquid (b.p., 83.6°) are highly explosive, particularly under pressure. The gas forms explosive mixtures with air. It burns with a smoky flame, but when supplied with sufficient air, it gives a clear white light. Its molecular heat of combustion at standard pressure is 320 kg.-cal. g. mol. Its cal.val. is *ca.* 1,500 B. Th. U./c.ft. compared with 500 in the case of coal gas. The large amount of heat thus evolved is made use of in the oxy-acetylene flame.

Acetylene reacts with several elements, and yields certain metallic derivatives, the chief of which is copper acetylide. It combines with chlorine to form additive compounds, but in sunlight the reaction may take place with explosive violence. It is reduced to ethylene, and in the presence of mercury salts it is converted into acetaldehyde. In recent years, these reactions have assumed very great technical importance and form the basis for the synthetic production of numerous open chain organic compounds.

Acetylene is also the starting material for the production of the synthetic rubber, known as chloroprene or neoprene, and vinyl resins and plastic. When heated acetylene is polymerized to benzene, and under the influence of heat and pressure it yields a complicated mixture of tars, oils and resins.

The first commercial use to which acetylene was put was as an illuminant. Though superseded to a large extent by electricity, acetylene is still widely used as an illuminant for marine and aeronautical purposes in buoys, light-houses, signalling lamps, etc. Large cylinders holding, in some cases, 500 c.ft. of dissolved acetylene and provided with automatic control and lighting devices are fitted to buoys.

At present the most important use of acetylene is in the welding and cutting industry. Nearly all metals can be welded by the oxy-acetylene flame which reaches a temperature of nearly 3,500°. The equipment consists of oxygen and acetylene cylinders, fitted with pressure reducing valves and regulators and a welding blowpipe. Blowpipes are available, suitable for welding the thinnest gauge of mild steel and also for welding steel up to 1" in thickness. Blowpipes have also been especially designed for the welding of lead sheet used in the construction of storage batteries. According to the type of blowpipe and the size of nozzle or welding tip, gas consumption may vary between 0.2 and 90 c.ft. per hour. Equal quantities of oxygen and acetylene are usually consumed during normal welding, but in special cases, it is possible to use a slight excess of acetylene. It is widely used for the welding of non-ferrous metals, particularly aluminium in aircraft and automobile industries, and for welding copper in chemical industry. When welding non-ferrous metals, it is usually necessary to employ a flux, the composition of which depends upon the nature of the material being welded. Oxy-acetylene welding finds its greatest scope in light engineering industry, and in the resurfacing of worn parts.

Acetylene is also used very extensively as a fuel gas for the oxygen cutting process. Its high calorific value, ready portability and ease of manipulation, particularly in the dissolved state, make it superior to most other fuel gases. It is also employed in blowpipes called pistols to melt wires used in metal-spraying.

The usual portable or semi-portable acetylene generator consists essentially of a container holding carbide, on which is placed a vessel of water, and the water is allowed to drip slowly on the carbide. The resultant gas is then passed direct to a suitable burner. Such small generating devices usually hold only a few pounds of carbide. Similar in principle, but sometimes larger in size, are automatic acetylene generators used for light welding equipment. In these, the carbide is placed in a small cage and allowed to dip into water. The pressure of the gas generated is employed to force water away from the carbide until the pressure is released. Generators of this type usually do not take a charge of more than 28 lb. of carbide at a single loading.

The larger types of generator work on the principle of dropping carbide into excess of water. It is usual to work with a weight of water four times that of carbide. By doing this, the temperature of the generator is kept fairly low and the resultant acetylene is free from products caused by overheating. Generators constructed on this principle are capable of taking a charge of up to two tons of calcium carbide.

The quantity of acetylene produced from calcium carbide depends on the quality of the carbide and on the size of grading. Theoretically one pound of calcium carbide should produce about 5.6 c.ft. of acetylene, but this figure is not attained in practice. The smaller the grading of the carbide, the lower is the yield. According to B. S. S. No. 642, good quality calcium carbide in sizes varying from 15 mm. to 120 mm. should produce in an efficient generator 4.8 c.ft. of acetylene per lb With the smaller portable generators, this figure may drop down to 4 c.ft. per lb. The pressure in acetylene generators is normally a few inches of water, but there has recently been a tendency to develop generators working at higher pressures. By law, it is not permitted to exceed a pressure of 9 lb. per sq. in.

The gas produced from commercial calcium carbide is not a pure product. It contains small amounts of the hydrides of phosphorus, silicon and sulphur. The two former are liable to spontaneous ignition in the presence of air. Further, the impurities have a tendency to corrode welding equipment and to choke the apparatus. Accordingly, in the larger installations, especially those preparing dissolved acetylene, the gas is passed through purifiers containing chromic acid, or ferric chloride and small amounts of copper and mercury salts (Thorpe, I, 75). The purified gas is then dried by means of calcium chloride, passed on to compressors and filled in steel cylinders at a pressure of 15 atm. or 225 lb./sq. in.

Dissolved acetylene cylinders contain a tightly packed porous substance which may take the form of mixture of special grades of charcoal, or a fibrous substance such as kapok, or a porous cement containing charcoal, asbestos, etc. This porous mass, saturated with acetone, breaks up the internal volume of the cylinder into innumerable small cavities. If the acetylene is compressed into a mass having the right degree of porosity (80 per cent.), decomposition of explosive nature is localised and arrested at the point of outbreak. The purpose of acetone is to increase the storage capacity of the container. The enhanced storage capacity of dissolved acetylene cylinders and the cleanliness and ease of manipulation of dissolved acetylene have been the prime factors for the rapid growth of the dissolved acetylene industry.

In '35, dissolved acetylene was being manufactured at Calcutta and Bombay, and additional units of production came into operation by about '44 at Lahore, Jamshedpur, Cawnpore, Bangalore and Colombo. Recently three more plants have been brought into operation at Madras, Burnpore and Rangoon. The value of dissolved acetylene produced rose from 4·5 lakhs of rupees in '38 to nearly 20 lakhs of rupees in '43. About 30 per cent. of the total production during the War was earmarked for the Govt.

Acetylene cylinders are in various sizes. The most common sizes are of 200 c.ft. (wt., 200 lb.), 120 c.ft. size (wt., 125 lb.), and 60 c.ft. (wt., 75 lb.). Dissolved acetylene cylinders are painted maroon, and are usually provided with a safety disc device which permits the contents being vented in the event of excessive gas pressure developing within the cylinder. The gas should not be withdrawn from these cylinders at too rapid a rate ; the max. rate advisable is about 20 per cent. of the total contents of the cylinder per hour, *i.e.*, from a 200 c. ft. cylinder not more than 40 c. ft. of acetylene should be drawn per hour. Acetylene cylinders should be stored in an upright position, away from heat or any contaminating substance and should be handled carefully and without undue violence.

The chief raw material of the acetylene industry is calcium carbide, and acetone is required as solvent. The Indian Oxygen and Acetylene Co. is reported to require annually about 25 tons of acetone to replace losses due to evaporation (Thomas, Rep. Develop. Industr. War Supplies, 1944, 38).

CALCIUM CARBIDE

Calcium carbide is manufactured in very large quantities in electrical furnaces in countries with abundant supplies of cheap electrical power. In modern furnaces, power consumption is about 3,500 kw.-hrs. per ton, and current efficiency, 62 per cent. The consumption of electrode is very high (over 70 lb. per ton of carbide), and forms an important item in its cost of production. The annual world production of calcium carbide before the War was of the order of 1½ million tons.

Calcium carbide is manufactured mainly for conversion into the fertilizer, calcium cyanamide, and for generating acetylene. For its preparation, high grade coke and limestone free from phosphorus are required. The coke must be low in ash content and the limestone (CaO, 97-98 per cent.) free from magnesium carbonate. The two are fed into the furnace in the ratio of 3 : 2 and raised to a temperature of over 2,000°. The molten carbide formed is run out, cooled and crushed to various grades. The largest carbide plants are in Canada, U. S. A., South Africa, Norway, Switzerland, France and Germany.

Pure calcium carbide is a colourless, transparent, crystalline solid. The commercial product (sp. gr., 2.2) consists of greyish black lumps, and contains about 80 per cent. of pure calcium carbide together with uncombined lime (14 per cent.) and carbon (1 per cent.), and traces of phosphides, sulphides and silicides. Owing to the readiness with which calcium carbide is acted upon by moisture, great care has to be exercised in its storage and transport, and on account of the inflammability of acetylene produced, it is necessary to protect it against risk of fire.

Calcium carbide has not been produced in India in any quantity, and attempts at small-scale production during the War have not proved economical. During the period

'35-39, the average annual imports amounted to 2,996 tons valued, at Rs. 6.6 lakhs. Of this, roughly 1,250 tons came from Canada, 1,200 tons from Japan, and the rest from South Africa and Norway. During '38-39, the price per ton of carbide, from Japan was Rs. 186, and from other sources Rs. 250 (*J. sci. & industr. Res.*, 1942, **1**, 13). Imports of carbide are subject to a revenue duty of 30 per cent. *ad valorem*.

During the War, consumption in India rose to nearly 5,000 tons per annum, and the annual requirements of the immediate post-war period are not expected to rise much above this figure.

ACIDS

Acids constitute an important group of chemicals which play a vital role in the industrial economy of a nation. In normal times, they are mainly utilized for conversion into products, used in other industries and in agriculture and medicine. During wars, there is an abnormal rise in the demand for free acids, particularly sulphuric and nitric, both of which are required for the manufacture of explosives.

Acids may be classified into two groups —inorganic or mineral, and organic. The first group is generally manufactured from mineral raw materials ; the second, from vegetable and animal sources. Recently, synthetic methods have been developed for the manufacture of some organic acids.

The more important members of the two groups are :

Inorganic—Boric, Hydrochloric, Nitric, Phosphoric and Sulphuric acids ;

Organic—Acetic, Citric, Gallic, Lactic, Oxalic, Stearic, Tannic and Tartaric acids.

The manufacture of hydrochloric, nitric and sulphuric acids, in India, commenced some forty years ago, and now only small quantities of special grades of these acids are imported. The country's requirements of almost all the other acids were met by imports even up to the commencement of the Second World War.

The last War gave a great impetus to the production of acids. The production of mineral acids, in some cases, was more than doubled, and attempts have been made to manufacture from indigenous raw materials acetic, oxalic, stearic and tannic acids. So far only the older processes of manufacture have been employed in India. New factories are expected to profit by the latest advances in other countries in processes and in plant construction.

INORGANIC ACIDS

Boric Acid

Boric acid, H_3BO_3, also known as boracic acid, occurs in soft, colourless, odourless crystals or flakes, or in the form of powder, melting at 184°. It is slightly soluble in water and alcohol, and can be crystallized from boiling water. It is steam-volatile and is a very weak acid. Its alkali salts in dil. solution are alkaline. B. P. acid and technical grades contain 99.5 per cent. of boric acid.

Boric acid is a mild antiseptic and its solutions are non-irritating. It is widely used as an external antiseptic in the form of dusting powder, ointment, lint, etc. Its use as a food preservative is now prohibited. In industry, it is employed in ceramic glazes and enamels, in impregnating candlewicks, fireproofing compositions, and paper glazes. It is also used in glass-making, plating, and as a flux.

The free acid is found in the vapours issuing along with steam from cracks and fissures in the ground in Tuscany, and is recovered from the condensed water by concentration. It is also prepared by the action of hydrochloric acid or sulphuric acid on a solution of borax :

$$Na_2B_4O_7+H_2SO_4+5H_2O\rightarrow4H_3BO_3+Na_2SO_4$$

EXPORTS OF BORIC ACID FROM
U. K. AND U. S. A. TO INDIA

Year	U. K.*		U. S. A.†	
	Cwt.	£	Cwt.	$
'40 ..	3,193	7,672	7,966	39,953
'41 ..	3,554	10,487	9,004	50,992
'42 ..	1,377	4,910	n. a.	n. a.
'43 ..	125	643	20,000	125,284
'44 ..	209	1,127	27,000	197,344
'45 ..	52	197	n. a.	n. a.

* *Tr. U. K.*, III ; † *For. Comm. & Navig. U. S.*

Hydrochloric acid

Hydrochloric acid is a solution of hydrogen chloride gas in water. 503 volumes of the gas dissolve in 1 volume of water at 0°. Hydrochloric acid forms a constant boiling mixture (sp. gr., 1.101 ; b.p., 110°/760 mm.) containing 20.24 per cent. of HCl. Solutions containing more than 36 per cent. of HCl (sp. gr., 1.2 and above) fume strongly when exposed to air, and are known as fuming acid.

The usual grades are Technical, C.P. and B.P., and all these are manufactured in India. B. P. acid (sp. gr., 1.159-1.168) contains 31-33 per cent. of HCl. Commercial acid, also known as muriatic acid, is marketed in grades of 18°, 20° and 22° Be'. corresponding to 28, 32 and 36 per cent. HCl, respectively. The usual impurities are iron and arsenic. A colourless synthetic product of high purity containing nearly 40 per cent. HCl is also available.

Hydrochloric acid is very corrosive and is generally packed in glass carboys or bottles, and stoneware jars. Recently rubber-lined containers and tanks have been finding increasing application both for transport and for storage.

Hydrochloric acid is mostly used in the manufacture of zinc chloride, and other inorganic chlorides, such as barium chloride and stannous chloride, and organic chlorides such as methyl and ethyl chlorides. It is used as a process material in the dyeing, mercerising and printing of textiles, in the chrome tanning of leather, in the manufacture of glue, and in the hydrolysis of carbohydrates. It is also used for pickling steel.

In medicine dil. hydrochloric acid (sp. gr., 1.0450-1.0452) which contains 10 per cent. by wt. of HCl, is used in stomachic and digestive mixtures, and in the treatment of achlorhydria associated with pernicious anaemia.

Hydrochloric acid was formerly obtained as a by-product of the Le-Blanc process for soda ash (q. v. under Alkalis), and was mainly used for the preparation of chlorine required for the manufacture of bleaching powder. Since the development of electro-chemical processes of alkali manufacture, producing large quantities of chlorine as by-product, hydrogen chloride is being produced by the combustion of hydrogen in silica burners in an atmosphere of chlorine. The gas formed is cooled and absorbed in water to give very pure hydrochloric acid.

Nowadays large quantities of hydrogen chloride are also formed during the technical chlorination of organic compounds, such as benzene, toluene, etc. This gas when purified and dissolved in water yields hydrochloric acid, which is comparable in purity to that obtained by the synthetic process. There are as yet no organic chemical industries in India involving the chlorination of organic compounds.

In India, till very recently the reaction between salt and sulphuric acid yielding salt cake and hydrochloric acid has been the only method in vogue for producing hydrochloric acid. The production of hydrochloric acid developed as an auxiliary industry, as soon as the manufacture of sulphuric acid became established in India. It is only during the last five years that the manufacture of the acid by the direct combination of hydrogen and chlorine has been undertaken by Messrs. Tata Chemicals and The Mettur Chemical and Industrial Corpn. Ltd. This process is of special significance to India on account of her deficiency in sulphur resources, and also offers an outlet for by-product chlorine produced during alkali manufacture.

SALT AND SULPHURIC ACID PROCESS

A charge consisting of common salt and sulphuric acid (60-66°Be′.) in quantities sufficient to convert half the salt taken into acid sulphate, is heated to about 150° in a cast iron retort. The hydrogen chloride evolved is cooled by means of a stream of water running over stoneware or silica coolers and passed through filters of stoneware towers packed with fine coke, in order to remove sulphuric acid present in the form of mist. The gas is then absorbed in an absorbing system made of fused silica or special stoneware, through which a current of water flows counter-current to the gas. S-bends and tourills are also being used for gas absorption.

Sodium bisulphate produced in the retort is made to react with an equivalent quantity of salt and roasted at about 540° in a muffle furnace, when a further equal quantity of hydrogen chloride is liberated and absorbed as before. In actual practice, depending on the type of equipment employed, the first and second stages of the above reaction may be carried out in the same vessel or in two successive reaction chambers. The acid produced by this method contains impurities, such as arsenic, iron and sulphuric acid carried over from the raw materials.

The salt cake left over at the end of the second reaction may be worked up to yield Glauber's salt.

Although theoretically it should be possible to bring about the complete conversion of sodium bisulphate to sodium sulphate, in practice, a certain amount is always left over unreacted in the final discharge mass. This obviously lowers the efficiency of the process with respect to sulphuric acid. Also, in the case of some of the older types of furnaces in vogue in India, due to lack of necessary mixing facilities, it is not uncommon to find unreacted salt in one part of the furnace, and sodium bisulphate in another.

The present consumption of hydrochloric acid in India is about 2,500 tons of commercial acid per annum, and very little of the acid is imported. The consumption of acid is likey to increase if it is more extensively used for pickling steel used in galvanizing and for tin-plate production.

PRODUCTION OF HYDROCHLORIC ACID IN INDIA

Year	Qty. (Cwt. of 100 per cent. acid)
'37-38	6,919
'38-39	7,212
'39-40	9,142
'40-41	9,142
'41-42	12,768
'42-43	12,711
'43-44	13,309
'44-45	13,002

The approximate pre-War cost of production in factories attached to sulphuric acid works was Rs. 175-180 per ton. During the War, this had risen to Rs. 340-350.

During the quinquennium ending '38-39, the average annual imports of hydrochloric acid were 752 cwt., valued at Rs. 17,142.

Hydrofluoric Acid

Hydrofluoric acid is an aqueous solution of hydrogen fluoride and technical grades usually contain 30-50 per cent. HF. The acid is prepared by distilling calcium fluoride with 90 per cent. sulphuric acid in a platinum or lead retort, and dissolving the gas in water.

Hydrofluoric acid attacks glass and is preserved in bottles coated on the inside with wax, or in bottles made of gutta-percha. The acid is highly corrosive, and considerable care is necessary in its preparation and handling.

Hydrofluoric acid is used for etching glass, for preparing frosted glassware, and for etching and engraving glass apparatus. Hydrofluoric acid dissolves silica and is used in the manufacture of ashless filter paper.

Nitric Acid

Among the mineral acids extensively used in the chemical industry, nitric acid is second only to sulphuric acid in value and in diversity of uses. The pure acid is a colourless, hygroscopic, strongly fuming, corrosive liquid. Commercial acid, however, is coloured yellow due to the presence of dissolved oxides of nitrogen. Chemically pure acid can be produced by distilling commercial grades, and the distillate, rendered colourless by blowing air through it. The constant boiling mixture (b. p., 120.5°/760 mm.) contains HNO_3, 68 per cent.

Although acids of varying strength are marketed, 70 per cent. nitric acid is the most common strength. Fuming nitric acid (sp. gr., 1.48) contains up to 86 per cent. nitric acid, while commercial 'Aqua-fortis' of 41.5° Be'. contains 65.67 per cent. nitric acid. While 'Aqua-fortis' may be used for the preparation of nitrates, and in certain chemical reactions, acid of strength above 90 per cent. is required for the manufacture of nitroglycerine, nitrocellulose, T.N.T. and various organic preparations. B. P. acid (sp. gr., 1.42) contains, HNO_3, 69 per cent.

Nitric acid is one of the most corrosive acids, and attacks most of the common materials, and hence great care must be taken in its transport. The common types of containers used have been glass carboys and earthenware jars. Special precautions have to be taken in the packing of such containers in wooden cases.

Nitric acid free from sulphuric acid does not attack pure aluminium. Tanks and drums of this metal are now being used for storing and transporting cold conc. acid. But the resistance of commercial aluminium containers is sometimes uncertain.

The largest use for nitric acid is in the manufacture of nitro-glycerine, gun-cotton, trinitro-toluene, picric acid, mercury fulminate, styphnic acid and several nitro-bodies which constitute the basis of the explosives industry. The acid is also used in the manufacture of dyestuff intermediates. It finds application in analytical work, in the refining of metals, particularly silver and gold, and in the manufacture of inorganic nitrates, such as silver nitrate, lead nitrate, copper nitrate, etc. Ammonium nitrate, which is an ingredient of the high explosive amatol, has recently received much wider application as a fertilizer.

The strong acid has a powerful caustic action and forms a convenient means of removing warts, but it should be used with caution. Burns from nitric acid should be treated immediately with sodium carbonate, subsequently with oil applied on lint, and covered with cotton. The dil. acid (10 per cent.) is a tonic and biliary stimulant.

The manufacture of nitric acid in India, till very recently, was being carried out almost entirely by the action of sulphuric acid on sodium nitrate. Most industrial establishments engaged in sulphuric acid manufacture produce nitric acid as an auxiliary product. The demand for nitric acid, particularly of the higher strengths, increased considerably during the War, and modern plants for the production of this acid by the catalytic oxidation of ammonia have been installed as subsidiary units in explosives factories.

The raw materials for the manufacture of nitric acid by this process are sodium nitrate (imported), and sulphuric acid. Difficulties of import during war years led to the substitution of sodium nitrate by indigenous potassium nitrate with increase in cost. The use of the latter during normal times in spite of its availability in India is uneconomical. In the retort process, conc. sulphuric acid in quantity sufficient to form acid sulphate is added to sodium nitrate in a cast-iron retort, connected to a water-cooled condensing system and an absorption train or tower for the absorption of residual uncondensed vapours. The cast-iron retort is mounted over a coal-fired furnace and heated to a temperature not exceeding 200°. It is desirable to maintain as low a temperature as possible, because of the ease with which nitric acid is decomposed by heat. The acid sulphate produced is liquid when hot, and is run out at the end of the charge and allowed to solidify ('nitre cake') in shallow trays of mild steel or cast-iron. Vapours of nitric acid which distil off are condensed, or are absorbed in the absorption system. The process yields conc. acid varying in strength from 70 to 99 per cent. and recovery is 85-90 per cent.

In the cataletic process, a mixture of air and ammonia containing 8.5-9 per cent. ammonia is passed over a platinum catalyst in a converter, maintained at a temperature of 800°-850°. The oxidation of ammonia to nitric oxide is exothermic and produces sufficient heat to maintain the converter at the optimum temperature and also to pre-heat the air required to 300°, in the preliminary heat exchangers. The gases leaving the converter consist of nitric oxide, water vapour, nitrogen and excess oxygen and are cooled to 20°-30°. Nitrogen peroxide formed at this low temperature is finally transformed to nitric acid in absorption tanks by a series of successive reactions. The acid produced has a concentration of about 50 per cent. and conversion efficiency of a 10-ton plant operating in India is said to be about 85-90 per cent.

Oxidation of ammonia may also be carried out under pressure (100 lb. per sq. in.) with smaller quantities of catalyst (about one-fifth). The acid produced is also of higher strength (60 per cent.). Its concentration can be raised to 90-95 per cent. by distilling it with strong sulphuric acid.

Indigenous production of nitric acid is carried out on a small scale at several places in the vicinity of consuming centres.

PRODUCTION OF NITRIC ACID IN INDIA

Year	Cwt.
'37-38	9,736
'38-39	11,763
'39-40	18,053
'40-41	12,665
'41-42	13,910
'42-43	19,041
'43-44	18,364
'44-45	14,445

Civilian requirements in India are about 760 tons of 65 per cent. acid. War Department demands are met by Ordnance Factories at Kirkee and Aruvankadu, which use ammonia oxidation process. Local supply is nearly equal to the demand, which till recently was in all 1300 tons (Rep. Heavy Chem. and Electro-Chem. Industr. Panels, 1947, 26).

During the quinquennium ending '38-39, the average annual imports of nitric acid amounted to 2,866 cwt., valued at Rs. 46,762. Germany and Norway were the chief suppliers.

During the pre-war period, Government Mints were the largest civilian consumers of nitric acid. The rest of the demand was confined to a number of miscellaneous trades, particularly silver and gold refineries. The development of new industries, such as the manufacture of dye-stuffs, nitro-cellulose lacquers, ammonium nitrate fertilizer and civilian explosives, will lead to an increase in the demand for this acid.

Phosphoric Acid

Anhydrous phosphoric acid can be obtained in colourless prismatic crystals, melting at 42.3°. Commercial grades generally contain H_3PO_4,50-90 per cent. In concentrations of above 85 per cent., the acid has a syrupy consistency. It is a strong non-volatile, tribasic acid, colourless when pure, and is miscible with water in all proportions. When heated, at about 250°, it decomposes yielding pyrophosphoric acid ($H_4P_2O_7$), and on further heating, metaphosphoric acid (HPO_3), also called glacial phosphoric acid. Strong phosphoric acid is highly corrosive.

Phosphoric acid and its salts are extensively used in industry (Killefer, *Industr. Engng. Chem.*, 1938, **30**, 967). The acid is mainly used for the manufacture of fertilizers (triple superphosphate and ammonium phosphate) and phosphates, and as a substitute for citric acid and tartaric acid in the manufacture of soft drinks. The acid is also widely used for pickling and dust-proofing iron, and in cleaning machinery.

Several sodium salts of phosphoric acid containing varying amounts of acid are used as water softeners, anti-corrosive agents and detergents. Indian Railways have started the treatment of boiler-feed water with trisodium phosphate ($Na_3PO_4.12H_2O$), and sodium hexametaphosphate $(NaPO_3)_6$. Disodium phosphate ($Na_2HPO_4.12H_2O$) is used in fire-proofing wood and paper, in ceramic glazes and as a preservative for cheese. Monosodium phosphate ($NaH_2PO_4.H_2O$) and acid calcium phosphate ($CaH_4(PO_4)_2H_2O$) are extensively used in baking powders.

Acid of medicinal grade should be free from arsenic and lead. The pure acid is used in a very dilute form as a gastric stimulant, and to quench thirst. Di- and monosodium phosphates are also medicinal. Disodium phosphate is a mild aperient, antacid and diuretic. It is also used as a saline cathartic. Calcium phosphate (B. P.) consists chiefly of a mixture of di- and tribasic calcium phosphates, with some monobasic acid calcium phosphate. It is insoluble in water, but dissolves in dil. mineral acids. It is useful as an antacid and is given in general debility, rickets, etc. Calcium glycerophosphate and hypophosphite form ingredients of several tonics.

MANUFACTURE

In the wet method for the preparation of phosphoric acid, finely divided calcium phosphate (from bone ash or phosphate rocks) is treated with dil. sulphuric acid in lead-lined steam-jacketed pans. Calcium sulphate formed is filtered and the dil. solution of phosphoric acid is concentrated up to 80-85 per cent. in pans, fitted with steam coils of lead. It is decolorized by activated charcoal, and filtered. The acid thus prepared is likely to contain combined arsenic, lead, iron, and also fluorine, when mineral phosphates are employed.

The concentration of phosphoric acid presents peculiar problems owing to the highly corrosive nature of the strong acid. It is purified in lead-lined pans by treating with a slight excess of sulphuric acid to precipitate calcium as sulphate. This forms a dense scale of lead sulphate which protects lead from further attack. If fluorine is present, powdered silica is added to combine with hydrofluoric acid. To remove iron, arsenic, etc., hydrogen sulphide is blown in until the acid is saturated (Badger and Baker, 131).

Phosphoric acid is also manufactured from phosphorus prepared in the blast furnace. Pulverized phosphate rock or bone-ash is mixed with carbon (ground coke), made into briquettes and heated with silica in a blast furnace. Silica displaces phosphorus pentoxide from combination, and the oxide is reduced by carbon to the element.

$$Ca_3(PO_4)_2+3SiO_2=3CaSiO_3+P_2O_5$$
$$P_2O_5+5C=2P+5CO$$

The vapours are passed through a condensation plant in order to obtain phosphorus, or mixed with air in special stoves and the element oxidized to phosphorus pentoxide. This, on hydration, yields 90 per cent. phosphoric acid (*Industr. Chem.*, 1939, **15**, 241). The chief impurity is arsenic which is removed by means of hydrogen sulphide, and recovery is about 90 per cent. In recent years, the electrical furnace has been displacing the blast furnace. Low grade phosphate rock, because of the better calcium oxide and silicon dioxide balance for slag formation, is sintered, mixed with coke and sand, and heated to 1300-1400°. Phosphorus liberated is directly converted into phosphoric acid by burning it in a tower with a water spray, or it may be condensed and collected under water, and subsequently oxidized to phosphorus pentoxide and hydrated to the acid (Shreve, 339). If the acid is to be used for the manufacture of triple superphosphate (*vide* Superphosphate), it is not necessary to free it from arsenic.

The dil. acid may be used directly for the preparation of phosphates. Disodium phosphate is obtained by treating phosphoric acid with one molecular proportion of sodium carbonate. From this monosodium phosphate is obtained by reacting with the requisite quantity of phosphoric acid, and trisodium phosphate by neutralizing with caustic soda. When monosodium phosphate and disodium dihydrogen pyrophosphate ($Na_2H_2P_2O_7$) are heated, they lose water, melt, and are converted into hexametaphosphate. On rapidly cooling the melt, hexametaphosphate is obtained in the form of a transparent glass (*Industr. Chem.*, 1935, **11**, 271). Acid calcium phosphate is prepared by dissolving di- or tri-calcium phosphates in phosphoric acid and allowing the solution to evaporate spontaneously. It is soluble in water.

The present Indian requirements of phosphoric acid are 30-40 tons of acid, and 120-150 tons of its salts per annum. This consumption is expected to increase and the Tariff Bd. (Rep. Phosphates and Phosphoric Acid Industry, 1947) estimates that the requirements of the country in the next 5 years will be 50 tons of acid, and about 300 tons of phosphates, excluding fertilizers.

In India, during '23-24—'27-28, Messrs. Dharamsi Morarjee Chemical Co., Ambernath, produced about 16 tons of phosphoric acid per annum, using bone-ash. Their plant was rated to produce 100 tons of acid per annum (Indian Tariff Bd., Enquiry Heavy Chem. Industry, 1930, I, Written Evidence, 60). During the last War ('39-45) the Star Chemicals, Bombay, encouraged by the Supply Dep., manufactured 20 tons of the acid in '45, and 50 tons of its salts. These, however, were only suitable for technical purposes, because the firm did not have suitable equipment for purifying the acid. So far, in India, only bone-ash has been used as raw material for the production of phosphoric acid. 4.8 tons of bones and 2.2 tons of sulphuric acid are required for the production of 1 ton of phosphoric acid (Tariff Bd., Rep., 1947)

The Tariff Bd. found that the existing revenue duties (30 per cent. on acid and 36 per cent. on salts *ad valorem*) afford sufficient protection to the manufacture of phosphoric acid and its sodium salts, and suggest that they may be converted into protective duties. In the case of acid calcium phosphate, however, they recommend a specific protective duty of Rs. 34 per cwt.

PHOSPHORUS

Phosphorus occurs in allotropic modifications. The white or yellow variety (*d*, 1.83 ; m. p., 44.4° ; b. p., 287°) is obtained first during the manufacture of phosphorus. After purification, it is cast into sticks in water-cooled moulds. It is a waxy solid insoluble in water, but readily soluble in carbon disulphide. It separates out in crystalline form when the solvent is evaporated. It is highly inflammable, and when exposed to air, it ignites spontaneously. It is therefore always stored under water. Owing to its poisonous nature, its use in the preparation of matches is now prohibited in most countries. It is now principally employed in rat-poisons and for preparing phosphorus compounds and phosphor-bronze.

Red phosphorus (*d*, 2.3 ; m. p., 725°) is formed when yellow phosphorus is heated at 240° in an inert atmosphere. Any unchanged yellow phosphorus is removed by grinding the material under water and treating it with caustic soda, which reacts with yellow phosphorus only. Red phosphorus is chemically less active and is stable to air and light. When heated in air, it takes fire at about 260°. It is insoluble in carbon disulphide and is non-poisonous. Its main use is in the match industry.

IMPORT OF PHOSPHORUS INTO INDIA

	Cwt.	Rs. (1000)
'38-39	2,301	1,22
'39-40 '43-44 (av.)	2,196	3,69
'44-45	39	10
'45-46	689	1,12

In '38-39 nearly 80 per cent. of the imports were from the U. K. and in the later years of the War, supplies came from Canada and the U. S. A.

Sulphuric Acid

Sulphuric acid has been known in Europe since the 14th century. The alchemist Geber first prepared it by the distillation of green vitriol (ferrous sulphate) and similar sulphates, and hence its name 'oil of vitriol'. It is now produced mainly by two processes: the chamber process and the contact process. In both sulphur dioxide is made to combine with oxygen and water to form sulphuric acid. In the first process, oxides of nitrogen are used to oxidise sulphur dioxide to sulphur trioxide, and in the second process the surface activity of different types of catalysts is utilized to bring about the oxidation. The demand for conc. acid and oleum for the manufacture of dyestuffs was largely responsible for the development of the contact process towards the close of the 19th century. Competition has led to improvements in technique in both processes, and at present each worked under proper conditions is contributing to meet various demands for the acid.

The first sulphuric acid plant in India was erected by Messrs. D. Waldie & Co. on the banks of the Hooghly, in 1890. This was followed by Messrs. Bengal Chemical and Pharmaceutical Works at Calcutta (1905), Parry & Co. at Ranipet (1904) and the Eastern Chemicals Ltd. at Bombay (1913). These units started sulphuric acid production mainly for manufacturing in their own works, heavy chemicals, such as hydrochloric and nitric acids, green copperas, epsom salt, aluminium sulphate, etc.

The industry made considerable progress after World War I, and more factories came into existence. Messrs. Dharamsi Morarji Chemical Co. started their factory at Ambernath near Bombay in 1922. New plants sprang up in the vicinity of coal fields to supply acid for the manufacture of ammonium sulphate from by-product ammonia.

In India, sulphuric acid was manufactured only by the chamber process till '35, when Messrs. Tata Iron & Steel Works established a contact plant at Jamshedpur. Thereafter, Messrs. Assam Oil Co., Digboi, Bengal Chemical and Pharmaceutical Works, Mysore Chemicals and Fertilisers, Belagola, and Sonawala Industries, Kalyan (Bombay), followed suit. These developments enabled India to produce her requirements of conc. acid for the manufacture of explosives during the last War.

RAW MATERIALS

Sulphur, iron pyrites, smelter gas and other waste gases containing sulphur dioxide, waste products of some industries, and gypsum are the principal sources from which sulphuric acid is manufactured. In '40, America produced 66 per cent. of her acid from sulphur, 22 per cent. from pyrites, and 11 per cent. from waste gases from zinc and copper smelters, and the rest from hydrogen sulphide from oil refineries. The use of sulphur has become almost universal for the operation of contact plants.

India has no significant deposits of sulphur or pyrites. The meagre deposits at Koh-i-Sultan (Baluchistan) were exploited during the last War, when imports became difficult. Unrefined ore from Baluchistan, containing a low percentage of sulphur, chokes up the chambers and towers by fine dust and necessitates frequent repairs to plants. The arsenical impurity present in the ore renders the acid unfit for accumulators and for the manufacture of food products. The small deposits of pyrites in Bihar and near Simla occur in comparatively inaccessible places.

Since the development of the gypsum process for the manufacture of sulphuric acid from anhydrite ($CaSO_4$) in Germany and the U. K., the large Indian occurrences of gypsum (q. v.) in the Punjab, Jodhpur, Bikaner and Trichinopoly are likely to form the raw material for the production of the acid in India in the future. The chief difficulty will be the transport of raw material over long distances to centres of acid production. But this may be overcome by producing sulphur from gypsum and transporting it. Anhydrite is also found in Rajputana and the Punjab.

Among the other possible sources of sulphur dioxide may be mentioned the waste gases from the copper smelters in Maubhander in Bihar. These are estimated to yield per day the equivalent of 20 tons of 100 per cent. acid (Dunn, *Rec. Geol. Surv. India*, 1943, **76**, *Bull. Econ. Min.*, No. 11, 57). These gases have not been made use of even during the last War when there was acute shortage of sulphur. According to Robson (Indian Tariff Bd. Rep. Heavy Chem. Industry, 1930, II, Oral Evidence, 370), copper pyrites in the ore, because of its low fusion point melts and clogs the furnace, when the ore is roasted for the production of SO_2. The proposed smelting of zinc concentrates (52,000 tons) at Jamshedpur is expected to yield sufficient sulphur dioxide to produce 42,000 tons of sulphuric acid. Further, it should be possible to recover the acid from spent acids, from some industries such as the pickling of metals. Several varieties of Indian coals have a high sulphur content, and a satisfactory method for its recovery will be of great economic value to the country.

India has been depending solely on imported sulphur for sulphuric acid manufacture. Most of her requirements were previously obtained either from Sicily or from Japan, but lately American sulphur is coming in larger quantities. The duty-free price of sulphur was about Rs. 90-100 per ton before the War, and went up to Rs. 250 per ton during the War. It is now (1947) Rs. 135 per ton at ports. The average annual pre-War consumption of sulphur for sulphuric acid manufacture was 10,000-12,000 tons, and it is now 28,000-30,000 tons.

Besides sulphur or sulphur-containing minerals, chamber plants require sodium nitrate, the consumption of which is 3-4 per cent. of the weight of sulphur burnt. This has been obtained so far, mainly, from Chile. Although recent developments in chamber plant design and operation have obviated the use of sodium nitrate by introducing catalytic ammonia oxidation unit for meeting the requirements of make-up oxides of nitrogen, no plant in India has so far taken advantage of the same. Potassium nitrate (*vide* Nitre) which may be used as a substitute is available in a crude form in the Punjab, the U. P. and Bengal, but imported sodium nitrate has always been much cheaper. The pre-War price per ton of sodium nitrate was Rs. 110-120, during the War, Rs. 450-460, and is now (1947) Rs. 380, f. o. r. Calcutta.

The contact process as employed in India requires the use of a vanadium catalyst on a suitable carrier, *i.e.*, diatomaceous earth. The catalyst is obtained from American firms and requires replacement only at long intervals.

MANUFACTURING PROCESSES

The roasting of sulphur or pyrites in a current of air is a common stage in both the processes, and various devices have been developed according to the raw material employed. In the case of pyrites, mechanical burners of special design are used for lumps or fines, while for sulphur, flat-bed furnaces or modern sulphur burners are employed.

Chamber process

Chamber plants in India have so far confined themselves mainly to the use of flat-bed furnaces, while contact plants are equipped with vertical or horizontal mechanical burners. In the operation of chamber plant burners, the requisite amount of sulphur is charged on to the flat-bed and allowed to burn in a current of air drawn in through suitable ports, and roasting is adjusted to produce a rich gas with a uniform composition of about 10 per cent. SO_2.

This gas passes through settling chambers and enters the Glover tower, after admixture with oxides of nitrogen, generated by the action of sulphuric acid on sodium nitrate. In the tower it comes into intimate contact with a mixed stream of chamber acid and nitrous vitriol trickling down in the form of a fine spray, and conc. and de-nitrated acid (60° to 61° Be'.) is drawn off from below the Glover tower.

The gases coming out of the top of the tower, along with steam generated in it, are successively passed through to a series of lead chambers. A spray of water or steam, depending on the design of the plant, is also introduced into the chambers. A continuous chain of reactions takes place resulting in the formation of an acid of 48°-54° Be'. which is tapped from below the chambers. The exit gases from the chambers, containing oxides of nitrogen, pass through the Gay-Lussac towers where they come into contact with the cold Glover acid (35° to 40°) which absorbs them completely. The waste gases going out of the Gay-Lussac tower consist primarily of nitrogen and some air, with traces of sulphur dioxide and oxides of nitrogen. The last two should be in negligible proportion in an efficiently operated plant.

The lead chambers may be of the air-cooled or of the water-cooled type ; the former, which are less efficient, are going out of use. Among recent developments in chamber plant design are the introduction of intermediate reaction towers between chambers so as to increase the efficiency of conversion ; the elimination of bulky chambers by towers occupying less ground area ; and operation at higher pressures. The chamber plants in operation in India, so far, have been of the simplest type, and in some cases intermediate reaction towers have been introduced.

It is possible to produce sulphuric acid of two different concentrations from a chamber plant :—60°-61° Be'., and 48°-54° Be'. To meet the demand for sulphuric acid of higher strengths, such as rectified oil of vitriol, the Glover discharge acid, or the chamber acid is transferred to concentrators. There are various types of concentrators, but only the cascade type is used in India. A series of quartz dishes is arranged stagewise and hot gases, from a coal or oil fired furnace, travel upwards from below counter-current to the acid flow. It is possible to produce acid of 95 per cent. strength in such a concentrator, but even under the best conditions the losses due to decomposition of the acid by heat amount to 7.5-12.5 per cent. In modern plants although high efficiencies of 98 per cent. and over are possible in the chambers, losses during concentration bring down overall efficiency to 90 per cent. and lower.

In a chamber plant, 784 lb. of sulphur and 22.4 lb. of sodium nitrate are required for the production of a ton of acid (Indian Tariff Bd. Rep. Heavy Chem. Industry, 1929, 6).

Contact process

In a chamber plant, the quality of raw material and impurities in the gas affect only the quality of the final product, but in the contact plant the damage is more serious. The quality of the sulphurous gas required for operation in a modern contact plant has to satisfy the following specifications :

(*i*) The percentage of sulphur dioxide should be 6-8, that of free oxygen being 10-13.

(*ii*) The gas should be dry and free from volatile arsenic and fluorine compounds ; it should be optically pure, *i.e.*, devoid of suspended impurities, so that a powerful beam of light when passed at right angles to the line of sight is not visible to the eye.

CONTACT PLANT

(Courtesy of Messrs. Fertilizers & Chemicals, Travancore)

In order to satisfy these conditions, it has become necessary to devise more refined methods of roasting the raw materials. Sulphur is weighed and dumped into a brick or concrete-lined melting pit, equipped with steam coils, and molten sulphur (120-130°) is pumped through a steam-lagged pipe and finally through a jet into a specially constructed furnace. Dust-free air drawn through a filter chamber, and dried in a tower by a downward spray of 93 or 98 per cent. sulphuric acid, is blown into the furnace in quantities sufficient to burn sulphur completely and to leave the required amount of excess air in the furnace gases.

The exit gases containing sulphur dioxide, after passing through the baffles in the furnace, are passed through a waste-heat boiler and then into a heat-exchanger, before being sent into the converter for effecting the combination of sulphur dioxide with oxygen. The temperature of furnace gases, which is about 800° at the time of leaving the furnace, is brought down to about 250° when they leave the waste-heat boiler. In the heat exchanger the temperature of the gases is brought up again to about 405° by utilizing heat from the converter gases, which is brought down from 560° to 410°.

The conversion is brought about in two stages so as to secure maximum efficiency. 80 per cent. conversion occurs in the primary converter (550°) containing 70 per cent. of the total catalyst mass, and the rest of it in the secondary converter (440°). In order to control the temperature in the two converters at optimum levels, it is necessary to cool the gases between these two stages and this is done by an intermediate heat exchanger. A total conversion efficiency of 98-99 per cent. can be secured by proper adjustment of conditions.

The gases issuing out of the secondary converter are again cooled by heat exchange before they are admitted into the absorber. In the absorber sulphur trioxide meets a continuous stream of 98 per cent. sulphuric acid. A steady stream of water or dil. acid is also admitted to maintain the concentration of the discharge acid at 98 per cent. The sulphuric acid poduced is cooled before storage. When oleum is required, its manufacture can be arranged by the addition of more absorption towers and readjustment of the acid cycle and operating conditions.

The contact process was first developed using finely divided platinum as catalyst, but platinum, besides being expensive, is very sensitive to impurities like arsenic, and only 85-90 per cent. of it can be salvaged. The vanadium catalyst captured the market immediately after its introduction on account of its cheapness, and immunity to arsenic poisoning. The cost of the contact plant was also considerably lowered, since the elaborate gas purification equipment necessary in the case of platinum catalyst was totally eliminated in vanadium plants ; but unfortunately the vanadium masses, though cheap, have little or no salvage value, and their royalty charges are high.

In a modern contact plant of 100,000 lb. capacity per day, 688 lb. of sulphur are required to produce 2,000 lb. of sulphuric acid (Shreve, 376).

According to Kreps (Economics of Sulphuric Acid Industry, 1937, 71), it is difficult to assess the relative merits of the two processes. Great differences exist in the cost of plants, using the same process or equipment. But, if the developments resulting from the introduction of vanadium catalyst continue to increase the competitive strength of the contact processs, the chamber process may soon become obsolete.

Contact plants are compact and occupy much less space than chamber plants, but require technical skill of a higher order for their operation. They have greater flexibility with regard to the strength of acid produced, and are best suited for the production of 98 per cent. acid or oleum. Oil of vitriol (66° Bé.) can almost always be made more cheaply by diluting contact acid than by concentrating chamber acid. For 60° Bé. (77.7 per cent.) and weaker acids, the choice between water-cooled chambers, vanadium and platinum contact plants is open, and depends upon local conditions. A chamber plant, however, has greater flexibility in production rate than a contact plant (Rogers, I, 250).

Gypsum process

In the gypsum process a mixture of calcium sulphate, sand, clay and coke is heated in rotary kilns to yield cement and sulphur dioxide. The furnace gases are thoroughly purified, and sulphur dioxide contained in them is passed on directly to a contact plant and converted into sulphuric acid. Although till now gypsum ($CaSO_4 . 2H_2O$), as such, has not been used for the manufacture of sulphuric acid, its application in the industry should not present any great technical difficulty.

GRADES

The following are the strengths in which sulphuric acid is usually marketed :

	Per cent. of H_2SO_4
Chamber acid 50°Be'.	62.18
Glover acid 60°Be'.	77.67
Oil of vitriol 66°Be'.	93.19
Contact 98 acid	98.00
Monohydrate	100.00
Fuming acid or 20 per cent. oleum	104.90
40 per cent. oleum	109.00
65 per cent. oleum	114.63

Besides strength, the quality of acid is indicated by the following grades : Commercial, Battery, C. P., and B. P. The commercial grade contains several impurities and corresponds to the quality of acid ordinarily run out of Glover tower, and is suitable for most industrial purposes. Battery acid must be of high purity. According to the specifications of Indian Stores Dep., it must be a clear, colourless and oily liquid of not less than 95 per cent. strength (sp. gr., not less than 1.840 at 15.5°), free from any suspended matter and sediment ; max. limits for non-volatile residue, 0.53 ; iron, 0.005 ; chlorine, 0.002 ; arsenic, 0.001 ; and total nitrogen, 0.005 per cent.

C. P. acid is chemically pure acid, and is obtained by distilling commercial acid and collecting the intermediate fraction, free from volatile and non-volatile impurities. B. P. acid should not contain more than 5 parts per million of arsenic, and 20 parts per million of lead.

HANDLING AND CONTAINERS

Sulphuric acid, particularly the grades containing the usual commercial impurities, attacks practically all metals under one condition or another. Even lead which is so widely used in sulphuric acid manufacture is safe only up to 80 per cent. concentration. Steel and ordinary cast iron, which are vigorously attacked by dil. acid, can be used with acids stronger than 93 per cent. (66° Be'.). Whereas only glass, fused silica and chemical stoneware were used for handling sulphuric acid some years ago, special ferro-alloys containing high silicon, nickel, chromium, and aluminium bronzes are now finding increasing application. For machinery parts exposed to the action of the acid, sometimes lead alloys containing tellurium or antimony and tin are also used.

Great care has to be exercised in handling strong sulphuric acid as it has a powerful dehydrating action and chars most organic substances when it comes into contact with them. Sulphuric acid burns should be washed with water and then treated with sodium bicarbonate followed by oil or sprayed with tannic acid solution.

In India, the acid is transported in stoneware jars of 2½ gal. capacity packed in wooden crates containing 1 or 2 jars. The jars are mainly of the wide-mouthed type with stoneware screw-stoppers, rubber rings being used for making them air-tight. A paste of kaolin clay and sodium silicate is put on the stopper for final sealing. The tendency has, however, been towards the introduction of narrow-mouthed, screw-stoppered stoneware jars, to enable the acid being poured out of the container more conveniently; but these have not been adopted widely due to difficulty in getting them. For larger packings, mild steel drums of 10-15 c.ft. capacity are used to transport 75 per cent. and stronger acid. Glass carboys of 4.5-5 gal. and larger capacities are also used for packing both conc and dil. acids.

USES

Sulphuric acid is one of the most important basic chemicals required both during war and peace. The production and consumption of this acid in any country is regarded as the index of its industrial status :

	1938 (Tons)	1944 (Tons)
U. K.	995,000	1,221,000
U. S. A.	3,772,900	8,205,360
India*	25,585	38,917

* Financial year, April—March.

Sulphuric acid is used mainly for the manufacture of fertilizers (ammonium sulphate, superphosphate), other acids (hydrochloric, nitric, phosphoric and chromic acids), and salts : dichromates, Epsom salt, green copperas, aluminium sulphate and alum, copper sulphate, zinc sulphate, etc. It is used in oil refining, the pickling of metals, the electrolytic refining of metals like copper, in electrical batteries, and in the manufacture of textiles, food products, synthetic drugs and dyestuffs, and explosives. In organic chemical industries it finds extensive application as a condensing, sulphonating and nitrating agent. The rayon industry consumes large quantities of acid, over 1.8 tons being required for the manufacture of 1 ton of rayon. The demands of the dyestuffs industry for sulphuric acid are also high.

The medicinal uses of sulphuric acid are not many. A very dil. solution (sulphuric acid lemonade) is taken by lead workers against plumbism, and is used as a preventive in cholera epidemics.

While new uses for the acid may be found with the progress of science and industry, the demand for some of the older uses is likely to diminish. Ammonium sulphate (q. v.) is preferably manufactured by the gypsum process. Production of hydrochloric acid is more advantageously carried out by the direct combination of hydrogen and chlorine, both of which are by-products of electrolytic caustic soda industry. Nitric acid is already being produced by the catalytic oxidation of synthetic ammonia ; blast furnace process for the manufacture of phosphoric acid has been successfully developed in other countries ; and Epsom salt is being obtained from bitterns.

ANALYSIS OF CONSUMPTION OF SULPHURIC ACID

(Ton of 100 per cent. acid)

	India Consumption in '44			Consumption in '46 in	
	Tons	Per cent. of total (a)	Five year target	U. K. (b)	U.S.A. (c)
Chemicals ..	21,000	37.7	35,000	101,214	1,780,000
Fertilizers ..	20,000	35.9	63,000	682,963	3,020,000
Metals	3,995	7.1	7,000	73,560	755,000
Cotton textiles ..	3,286	5.9	5,100	18,614	75,000
Govt. purchases	2,236	4.0	1,000	..	..
Mineral oil ..	1,611	2.9	2,000	29,962	1,000,000
Leather ..	790	1.4	1,000	4,863	..
Battery acid ..	410	0.7	1,000	8,698	..
Distillery ..	318	0.6	1,000		..
Rayon industry	..	..	34,000	110,361	556,000
Plastics ..	..	..	..	16,435	..
Dyestuffs and intermediates	..	..	..	59,377	..
Explosives ..	n. a.	n. a.	..	12,723	105,000
Unclassified ..	2,114	3.8	2,500	101,898	345,000
Others	..	..	..	176,686	1,060,000
	55,760	100.0	152,600	1,397,364	8,696,000

(a) Rep. Heavy Chem. & Electro-Chem. Industr. Panels, *loc. cit.*, 63.

(b) *Chem. Tr. J.*, 1947, **120**, 168.

(c) *Chem. Engng.*, 1947, **54**, No. 2, 109.

Nearly 75 per cent. of sulphuric acid now produced in India is used for the manufacture of chemicals and fertilizers. Expansion in the production of superphosphates and ammonium sulphate, and the development of new industries, like rayon and dyestuffs manufacture, will lead to a greatly increased demand for the acid.

The development of sulphuric acid manufacture in India has not been properly planned, although the capital invested in the industry exceeds a crore of rupees. Most of the units are small and uneconomical. The price of the acid can be lowered by increasing plant capacity, but this is not considered practicable in India since centres of consumption are widely scattered.

DISTRIBUTION OF SULPHURIC ACID PLANTS AND PRODUCTION IN INDIA IN 1944

Area	No. of plants	Production (Tons of 100 per cent. acid)
Bengal	5	13,000
Assam	1	1,490
Bihar	5	19,000
United Provinces	3	4,900
Delhi	5	3,000
Punjab	5	2,706
Sind	1	30
Bombay	3	7,900
Baroda and Ahmedabad	3	1,230
Mysore	1	4,170
Madras*	1*	1,680
Hyderabad	1	160
	34	59,266

* Excluding the chamber plant (3,000 tons/year) of the Cordite Factory at Aruvankadu (Nilgiris).

In '44 there were 30 chamber plants and 5 contact plants. Many of the chamber plants were of small capacity (10-12 producing less than 500 tons per annum), and there were only 6 chamber plants of capacity more than 3,000 tons, two in Bengal, one each in Bihar and the U.P., and 2 in Bombay. The contact plants were located in Bengal (10 tons/day), Mysore (25 tons/day), Bihar (50 tons/day), Assam (5 tons/day), and Kalyan (10 tons).

Though the capacity of the Indian sulphuric acid industry before the War was 57,000 tons per annum, the average annual production in the quinquennium ending '38-39 was only 27,000 tons. During the War a number of locally improvised chamber plants were installed in various places, and in '44 the capacity rose to over 65,000 tons and production reached a peak of 59,000 tons.

Recently 4 new contact plants of 3,000 tons capacity have been erected, one each, in Bengal, Bihar, Delhi and Bombay. The contact plant (75 tons/day) of Messrs. Fertilisers and Chemicals, Travancore, has also come into production. But this plant is expected to release only 3,000 tons of acid into the market.

The five-year target for production has been placed at 118,600 tons, excluding the requirements of the rayon and dyestuffs industries (Rep. Heavy Chem. & Electro-Chem. Industr. Panels, *loc. cit.*, 2). The largest demands are for expansion in the production of fertilizers and chemicals, the former requiring 63,000 tons, and the latter 35,000 tons of acid per annum. The Heavy Chemicals Panel is of opinion that 20-25 tons/day plants are economic units, but taking into consideration Indian conditions, they recommend the distribution of 10 tons/day units in various parts of the country.

PRICES

During '32-38 the highest quotations in the Bombay market for commercial sulphuric acid (*d*, 1.840) varied from Rs. 122-129/ton. After the declaration of War, there was a sudden rise in prices, and in '42 the Govt. of India introduced control. The following were the controlled prices in '45, sulphur being charged to the works at Rs. 200/ton :–

	Rs.
Chamber acid—	
d, 1750	205-257
d, 1..840 (Commercial)	275-332
d, 1.840 (Refined)	305-362
Contact acid—	
d, 1.840	220

Since the end of the War, prices have declined slightly, and recently the control has been lifted. Commercial chamber acid (*d*, 1.840) is now (Aug. '47) quoted at Rs. 280-320 and contact acid of the same density, at Rs. 180-250.

The price of the acid usually depends upon the cost of sulphur, and the size of the plant, 1/3 ton of sulphur being required for one ton of acid. In '45 American sulphur was quoted in the English market at £12/ton, and the price of the acid (*d*, 1.840) was £7/ton. Indian prices of sulphur (pre-War, Rs. 90-100/ton) and sulphuric acid (pre-War, Rs. 120-129/ton) do not show similar relationship, and the high price of the acid has been responsible for retarding the development of chemical industry in India.

Imports of sulphuric acid have been negligible, because of the difficulty in transporting conc. acid in bulk across seas, and consequently, Indian manufacturers enjoy a virtually protected market. According to the Tariff Bd. (Rep Bichromates Industry, 1947, 13), in '46, when the price of sulphur was about Rs. 150/ton, the acid was being marketed at Rs. 280/ton. The price of the acid should ordinarily be equal to the cost of 0.33 ton of sulphur *plus* conversion charges, about Rs. 30. The Board remarks that even if every possible allowance is made for increased costs of conversion, freight, etc., there is no justification for a price higher than Rs. 160/ton. There is urgent need for an enquiry into the economics of the industry in India, and for the rationalization of production and distribution.

ORGANIC ACIDS

Acetic Acid

Acetic acid is a constituent of vinegar in which it occurs to the extent of 3-5 per cent. The pure acid is a clear colourless liquid with a pungent odour (sp. gr./15°, 1.055 ; m. p., 16.7° and b.p., 118°). It is also called glacial acetic acid, because when cooled, the crystals formed resemble ice flakes. The acid is soluble in water, alcohol and ether, and is also a valuable solvent. The strong acid has a corrosive action on the skin, and acids of moderate concentration have a sharp, acid taste.

Large quantities of acetic acid are required for the manufacture of acetate rayon, esters and lacquers, and varnishes (*Industr. Engng. Chem.*, 1931, **23**, 482). It is also used in food industries. In India, the acid is mostly employed for the coagulation of rubber latex, and for the manufacture of pigments like white lead, verdigris, etc. It is also employed in the preparation of acetates and acetic esters, and in the dyeing and printing of textiles. In medicine, the strong acid is used as a rubefacient ; the dil. acid is diaphoretic, diuretic and expectorant.

In the older process of preparing acetic acid from the products of wood distillation, the grey acetate of lime (calcium acetate) is decomposed by conc. sulphuric acid, and the acid distilled over usually contains 80 per cent. of acetic acid. When this is further concentrated by rectification, glacial acetic acid (96-98.5 per cent.) is obtained. This is treated with a small quantity of potassium permanganate and refractionated to yield chemically pure acid.

Acetic acid is now recovered directly from pyroligneous liquor by cold extraction of de-alcoholized pyroligneous liquor with ethyl ether or ethyl acetate. In the Suida process, extraction with high boiling wood oils is carried out in the vapour phase, and acetic acid is recovered subsequently by vacuum distillation. In the Othmer process, after the removal of crude methanol, the liquid is heated and the vapours pass into an azeotropic dehydrating column, where they meet with butyl acetate which acts as the withdrawing liquid. The ester distils with water as the min. boiling azeotrope, and yields acetic acid containing as little as 0.5 per cent. water. In order to purify the acid, it is treated with a small quantity of sodium dichromate and redistilled (Shreve, 682).

Acetic acid is now manufactured mainly by the synthetic process. In this, acetylene is converted into acetaldehyde, and the latter oxidized to acetic acid. The acid formed is of high concentration and purity.

The synthetic acid is cheaper and has displaced, to a large extent, the acid from wood distillation products. Over 75 per cent. of acetic acid manufactured in the U. S. A. is by this process (Rogers, I, 18). Acetic acid can also be produced by the vinegar process and by the direct oxidation of alcohol.

The commercial acid is sold in carboys, barrels or glass bottles, in concentrations varying from 30-99 per cent.

The present Indian consumption of acetic acid is estimated at 400 tons per annum. The average annual imports during '34-39 were about 300 tons, valued at Rs. 1.15 lakhs. This quantity could be obtained from the wood distillation plant of he Mysore Iron Works, if arrangements are made for the direct recovery of acid from pyroligneous liquor. During the War, small quantities of acetic acid were manufactured from grey acetate of lime.

ACETATES

Some of the salts of acetic acid are used in medicine, and in industry. Ammonium acetate prepared from acetic acid and ammonia is a mild expectorant, diuretic and diaphoretic. Sodium and potassium acetates, prepared by neutralizing acetic acid with the corresponding carbonate, are also employed in medicine as diuretics. Lead acetate is an important salt, and is prepared by dissolving finely divided litharge (PbO) in acetic acid. In medicine, it is used for preparing soothing and astringent lotions ; in industry, in dyeing, calico-printing, and in the manufacture of chrome yellow and other pigments. Aluminium and iron acetates are used in the textile industry. Of the esters of acetic acid, amyl, butyl and ethyl acetates are prepared on a large scale for use as solvents. Some esters are also used as perfumes and flavouring materials. Acetate rayon is made from cellulose acetate.

Citric Acid

Citric acid, $C_6H_8O_7$. H_2O, is present in the juice of several acid fruits, such as citrus fruits, pine-apples, etc. The pure acid crystallizes in large colourless rhombic prisms and does not have any odour. When heated, it loses its water of crystallization above 130°, and the anhydrous acid melts at 153°, and decomposes on further heating. Citric acid is readily soluble in water, less soluble in alcohol, and only sparingly soluble in ether.

The acid is mainly used in the preparation of medicinal citrates, confectionery, and soft drinks and effervescent salts. Small quantities are employed in silvering and engraving, and in dyeing and calico-printing. Imports into India were mainly from Italy, and the average annual imports during the quinquennium ending '38-39 were about 120 tons, valued at Rs. 1.33 lakhs.

Until recent years, citric acid was manufactured from citrus juices, and Italy and California were the largest producers. In Hawai the acid is also manufactured from pine-apple juice. Tobacco waste contains a large proportion of citric acid and forms a potential source.

Clarified lemon juice from off-size or off-grade fruit (4.5-6 per cent. of citric acid) is heated and neutralized with finely powdered calcium carbonate (free from magnesium carbonate). The precipitate of calcium citrate is filtered while the liquor is still hot, washed thoroughly with hot water, and dried rapidly. The salt is more soluble in cold water than in hot water. Technical calcium citrate contains usually 67-70 per cent. of citric acid.

For the manufacture of the acid, a slight excess of sulphuric acid is added to a suspension of crude calcium citrate in water. The mixture is vigorously stirred and boiled

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and the precipitated calcium sulphate is filtered off. The acid liquors are concentrated in vacuum evaporators. The crude acid, which crystallizes on cooling, is purified by recrystallization. The yield of acid from lemons varies from 15-50 lb. per ton of fresh fruit.

Patel and Kale (*Dep. Industr., Bombay, Bull.* No. 11, 1938) have experimented on the production of calcium citrate from lime (*Citrus medica* and *C. acida*) grown in Bombay. When worked directly for the production of calcium citrate, these limes yield on an average 82 lb. of salt per ton. If calcium citrate is recovered as a by-product from the sludge left after treatment for obtaining the volatile oil, the yield goes down to about 65 lb. per ton. Neutralization is carried out by the gradual addition of a thin suspension of slaked lime in water. To ensure the quality of calcium citrate produced, it is necessary to see that the reaction mixture does not become alkaline at any stage during the addition of lime. When the acid concentration falls below 0.1 per cent., the point of contact with the suspension of lime becomes darkish-brown, and the precipitate turns greenish-yellow. Addition of lime should be stopped at this stage and, if necessary, a small quantity of fresh acid juice added (*Bull. imp. Inst. Lond.*, 1929, **27**, 335).

In recent years, large quantities of citric acid are being manufactured in America by the fermentation of sugar using certain strains of *Aspergillus niger*. The reaction takes place according to the following equation :

$$C_{12}H_{22}O_{11}+H_2O+O_2 = 2C_6H_8O_7 + 4H_2$$

The spores of a suitable organism are introduced into sterile sugar solutions (15-20 per cent.), with low concentrations of ammonium nitrate, contained in shallow pans of pure aluminium. Fermentation is started in an acid medium (pH, 3.5), and it is usually complete in 7-10 days. The yields of citric acid is about 60 per cent. by weight of sugar taken. The entire process has to be carried out under perfectly sterile conditions (*Industr. Engng. Chem.*, 1938, **30**, 266; *vide* also Chatterjee, *J. Indian chem. Soc.*; *Industr. & News Ed.*, 1942, **5**, 201).

Potassium citrate has diaphoretic, diuretic and febrifuge properties. Sodium citrate is an anti-coagulant and is used in blood transfusion. It is also added to milk for feeding infants and invalids, to prevent the formation of curds. Iron ammonium citrate (Fe, 20.5-22.5 per cent.), a complex ferric ammonium citrate, occurs in thin dark-red transparent deliquescent scales, with an astringent taste. It is commonly used in debility and anaemia. A green variety (Fe, 14-16. per cent.) containing a larger proportion of citric acid is used for hypodermic injection.

Gallic Acid

Gallic acid ($C_7H_6O_5 . H_2O$), 3. 4. 5 trihydroxybenzoic acid, forms pale yellow or colourless needles, melting at 222°. It is soluble in alcohol, but sparingly soluble in ether and water. Unlike tannic acid, its solution in water does not give precipitates with albumen or gelatine solutions.

Gallic acid gives a brown colour with ferrous sulphate which becomes black on exposure; hence it is used in the manufacture of writing ink. Some important anthraquinone dyestuffs, such as alizarin brown, are manufactured from gallic acid. It is also a source of pyrogallol. A basic bismuth salt, known as dermatol, is used in dysentery and diarrhoea, and also as an antiseptic dusting powder.

Gallic acid is found in many plants containing gallotannins. The acid is prepared by the acid or alkaline hydrolysis of tannins or tannic acid. It is also obtained technically from extracts of gallotannins by fermentation. Certain moulds of the

Aspergillus spp. contain an enzyme, tannase, which breaks down tannin into glucose and gallic acid (*Industr. Engng. Chem.*, 1930, **22,** 1174). Fermentation is carried out under sterile and aerobic conditions until tannin has completely disappeared ; gallic acid is then recovered from solution. Technical grades contain 55-58 per cent. of acid.

Pyrogallol

Pyrogallol, $C_6H_6O_3$, also called pyrogallic acid, is 1.2.3. trihydroxybenzene. It is obtained when gallic acid is decarboxylated by treating it in an autoclave with 3 times its weight of water. Crude pyrogallol is purified by sublimation in vacuum. Pure pyrogallol forms white lustrous crystals melting at 133°. It is soluble in water, alcohol and ether. It is a strong reducing agent, and is used in photography as developer. An alkaline solution of pyrogallol rapidly absorbs oxygen and turns brown ; it is employed in gas analysis for removing oxygen. Pyrogallol has a toxic action on blood and blackens skin. It is sometimes used in ointments for skin diseases, and forms an ingredient of hair dyes.

Lactic Acid

Lactic acid, $C_3H_6O_3$, is a yellow or almost colourless, viscous, hygroscopic liquid (sp. gr., 1.249), readily soluble in water, alcohol and ether The commercial acid is optically inactive. It cannot be distilled at ordinary pressure, but at a pressure of 14 mm., it boils at 122°. The acid is marketed in several grades in concentrations of 22-44 per cent., and sometimes even 85 per cent. Bottles, barrels and carboys are used as containers.

Lactic acid is now largely used for deliming hides during their preparation for tanning. It finds use in chrome-mordanting, and in the acid dyeing of wool. It is also used in several foods, drinks and candies.

Lactic acid is one of the oldest acids known, and it is present in sour milk. It is obtained as a by-product of the dairy industry. Lactose or milk-sugar, present in whey, is fermented by lactic bacilli (*Lactobacillus bulgaricus*). Other lactic bacilli, such as *L. delbrucki***,** are able to ferment dextrose, and molasses may also be used as raw material. Fermentation proceeds best at pH, 5-5.8, and temperature, 40-45°, and is complete in 5-6 days. In order to control acidity, chalk is added from time to time and the acid produced is converted into calcium lactate. The solution of calcium lactate is heated to coagulate protein matter, filtered and concentrated. On cooling, the salt crystallizes out and is purified by recrystallization.

Calcium lactate is an efflorescent salt. It is completely soluble in water and is used in medicine to increase the coagulability of blood. Along with vitamin D, it is administered in cases of calcium deficiency.

The salt when treated with sulphuric acid gives lactic acid. After the filtration of calcium sulphate, lactic acid can be concentrated up to 50 per cent. Further concentration presents peculiar difficulties owing to the highly corrosive nature of lactic acid. Concentration up to 80 per cent. may be carried out in vacuum evaporators made of stainless steel containing molybdenum (*Chem. Engng. News*, 1944, **22,** 440).

Oleic Acid

Oleic acid is present in the glycerides of most fats, particularly liquid fats or oils, such as olive oil, cotton seed oil and coconut oil. The pure acid, $C_{18}H_{34}O_2$, is a tasteless, odourless, oily liquid of slightly yellowish colour (iod. val., 90) On cooling, it solidifies into colourless needles, melting at 14°. It is converted into a solid isomer, elaidic acid, melting at 45°, by action of nitrous acid at 200° in the presence of sulphur dioxide or sodium bisulphite. Oleic acid is insoluble in water but dissolves readily in alcohol and other organic solvents.

The technical product is also known as red oil, and depending upon its purity varies in colour from yellow to deep red or reddish brown. It is obtained as a by-product in the manufacture of commercial stearic acid, and usually contains not more than 70 per cent. of oleic acid. Its iod. val. is 85-95, due to the presence of linoleic and saturated acids in more or less equal proportions.

Red oil is used in the manufacture of soft soaps, oleates, and for oiling wool. The purer grades obtained by distillation are used for the preparation of ointments and polishing compounds.

Oxalic Acid

Oxalic acid occurs in several plants as potassium acid oxalate or calcium oxalate. The pure acid, $C_2H_2O_4 \cdot 2H_2O$, crystallises in large transparent colourless rhombic prisms, and is soluble in water (1 in 12). When heated, it melts in its water of crystallization at 98°, begins to lose water and becomes anhydrous. At higher temperatures (*ca.* 150°) it volatalizes with partial decomposition. The acid and its soluble salts are poisonous. In oxalic acid poisoning calcium hydroxide or calcium carbonate made into a cream with water, is administered as an antidote, when the insoluble calcium salt is precipitated out.

Oxalic acid is mainly employed in the printing and dyeing of textiles. For this purpose some of its salts, such as antimonyl potassium oxalate, $K_3Sb(C_2O_4)_3$, $3H_2O$, are also used. The free acid is employed for bleaching straw, wood, and cotton linters. It is an ingredient of several inks and metal polishes. Since the acid forms soluble iron compounds, it is employed for removing ink and iron stains. For these purposes, potassium quadroxalate (also known as salt of sorrel), $KH_3\ (C_2O_4)_2 \cdot\ H_2O$, is also employed. Ferrous potassium oxalate, $FeK_2\ (C_2O_4)_2 \cdot 2H_2O$ is a powerful reducing agent, and is used in photography as oxalate developer.

The average annual imports of the acid into India during the quinquennium ending '38-39 were 150 tons, valued at about a lakh of rupees.

Oxalic acid was formerly made by heating sawdust, preferably from softwoods, with sodium hydroxide to 200-240°. The fused material is extracted with water and the calcium salt precipitated. The free acid is liberated by sulphuric acid, recovered from solution, and purified by recrystallization. In a similar manner it can also be prepared from starch or sugar. Very pure oxalic acid is obtained by oxidizing sugar by conc. nitric acid. The commercial acid (99.5 per cent. pure) is usually sold in the form of crystals or powder.

Oxalic acid is now prepared by the formate process. Sodium formate is formed when sodium hydroxide is heated with carbon monoxide at a pressure of 8-10 atms. and a temperature of 200°. When this is further heated to 375° under reduced pressure, it decomposes yielding sodium oxalate and hydrogen. The reaction is said to proceed at 290° if heated with small quantities of alkali (less than 5 per cent.). The calcium salt is precipitated, and the acid recovered as before. The new process has superseded, to a large extent, the sawdust method.

Small quantities of oxalic acid were manufactured in India during the last War. The bark of *Treminalia arjuna* is said to contain a high percentage of calcium oxalate. It was also used for the recovery of oxalic acid, after the extraction of tannin.

Stearic Acid

Stearic acid, $C_{18}H_{36}O_2$, is one of the most widely distributed fatty acids, and occurs in combination with glycerol in numerous oils and fats. Particularly rich sources are tallow and the seed-fats of some species of Dipterocarpaceae, Guttiferae and Sapotaceae. It is also formed by the reduction of oleic acid. Pure stearic acid is a colourless, odourless, crystalline material (m. p., 69°) which is insoluble in water. It dissolves readily in alcohol and other organic solvents.

Technical stearic acid, sometimes incorrectly called stearin, prepared from tallow, is invariably a mixture of stearic and palmitic ($C_{16}H_{32}O_2$) acids, and is usually marketed in the following grades :

	M. p.	Iod. val.	Oleic acid
		(Per cent.)	
Single pressed' ..	51.5-52.2°	12-14	15
Double pressed' ..	53.9-54.4°	5-6	10
Triple pressed' ..	54.4-55.0°	3	5

Large quantities of stearic acid are used in the manufacture of candles, and in rubber compounding. Stearic acid is also used in the preparation of cosmetics, and in ointments as a substitute for wax, and for preparing castor oil suppositories. When partly neutralized, it forms a cream base with 5-15 times its weight of aqueous solutions, and is used in this form in vanishing creams. The acid is also used in preparing metal and shoe polishes. A solid fuel prepared from stearic acid and alcohol ignites readily and burns without leaving any ash.

Stearic acid imparts hardness to soaps, and potassium stearate is an ingredient of shaving soaps. Some of the metallic stearates such as those of aluminium, calcium, magnesium and zinc, are used in special lubricants, paints and varnishes, and in certain printing inks. Aluminium stearate is also extensively employed for the waterproofing of fabrics.

Tallow (from cattle, sheep, hogs and horses) is the principal material for the manufacture of stearic acid. Some of the seed-fats suggested as subsitutes for tallow (Puntambekar, *J. Indian chem. Soc., Industr. & News Ed.*, 1938, **1**, 163) may also be employed for the manufacture of stearic acid.

Fat	M. p. of fat	Palmitic acid	Stearic acid
		Per cent. of mixed fatty acids	
Beef tallow* ..	40-50°	29	21
Mutton tallow*	41-50°	25	31
Bone fat† ..	41-45°	20-21	19-21

*Hilditch, 136 & 170 ; †Kingzett.

Species	Name of fat	Per cent. of fat in seeds	M. p. of fat	Palmitic acid	Stearic acid
				Per cent. of mixed acids	
1. *Garcinia cambogia*	Gamboge butter	31	30°	..	50
2. *Garcinia indica*	Kokum butter	23—26	40—43°	5	52
3. *Garcinia morella*	....	58 (kernels)	34—37°	7	43
4. *Madhuca butyracea*	Phulwara butter	50	39—51°	57	4
5. *Madhuca indica* } ..	Mahua Oil	50—60	48° *	16—24	19—25
6. *Madhuca longifolia* }			30° *		
7. *Shorea robusta*	Sal butter	16	26.5°	..	47
8. *Vateria indica*	Dhupa fat	22—27	30—40°	10	39

(1) & (7) Rau and Simonsen,, *Indian For. Rec.*, 1922, **9**, iii, 12 & 14 ;
**Bull. Indian Industr. Res.*, No. 10, 1943, 64 ; rest, Jamieson.

In preparing stearic acid from tallow, the raw material is purified by cooking it with dil. sulphuric acid for about an hour and a half, using live steam. It is then saponified by Twitchell or similar reagent prepared by heating a fatty acid, and an aromatic hydrocarbon, such as benzene or naphthalene with strong sulphuric acid (Hilditch, 175). The cleaned fat is mixed with 20-50 per cent. of its weight of water, some dil. sulphuric acid and 0.75-1.25 per cent. of the reagent, and boiled with open steam for about 18-20 hours. The sweet water (glycerol) is run out and the mixture is given a second boiling when nearly 97-98 per cent. of hydrolysis is completed. The crude acids are removed and allowed to cool and solidify. The cakes thus formed are wrapped in cloth and cold-pressed for about 2½ hours. This gives the 'single pressed' acid. This is melted, solidified into cakes, and is subjected to two pressings in a hot press, through which steam at 120 lb. pressure is passed. The first hot pressing (3-3½ min.) gives the 'double pressed' acid and the second hot pressing (5-6 min.) gives the 'triple pressed' acid. Each grade is melted and boiled with sulphuric acid to improve its colour. Ultimately the product is cast into slabs (*Industr. Engng. Chem.*, 1929, **21,** 719). If the raw material is of very low grade, the crude acids are purified by distillation in vacuum, using copper stills.

Fats are also split into their constituents by autoclaving them with water, using certain basic oxides like lime, magnesia and zinc oxide as catalysts (2-4 per cent. by wt.). Steam is admitted into the closed autoclave and kept at a pressure of 100-120 lb. per sq. in. for 10-12 hrs., when nearly 98-99 per cent. of fat is hydrolysed. When the reaction is complete, the mixture is blown out into a tub, and the upper layer, after the removal of sweet water, is mixed with dil. sulphuric acid and boiled with steam in order to purify it. Fat hydrolysis can also be effected without the use of catalysts at higher temperatures and pressures.

In the quinquennium ending '38-39, the average annual imports of stearic acid into India amounted to 2,260 tons, valued at Rs. 5.0 lakhs. During the War a few Indian companies manufactured stearic acid from tallow, *mahua* oil (*Madhuca indica*), and hydrogenated oils. The quality, however, was poor. The acid produced was mostly used for the preparation of aluminium stearate, required for waterproofing fabrics. Owing to heavy demand the prices of acid rose up to Rs. 3 per lb.

Tannic Acid

Tannic acid or tannin is a constituent of several tannin bearing plant materials (leaves, fruits, bark, and sometimes also wood). The pure acid, also called gallotannic acid or digallic acid, has the formula $C_{14}H_{10}O_9$. It forms a pale yellow, amorphous powder, readily soluble in water, alcohol and acetone, but insoluble in ether. When heated, it decomposes at 210°. Tannic acid is strongly astringent, and has reducing properties. It gives precipitates with lead salts, alkaloids and proteins.

In tannic acid or gallotannin, digallol residues are found combined with glucose. The technical product is a yellowish white or light brown powder with a characteristic odour. Some commercial samples also contain gallic acid. They are used only for technical purposes such as dyeing (as mordant), and manufacture of ink. Extracts of materials containing gallotannins also may be used for technical purposes.

Tannic acid of high purity is used for medicinal purposes. It is prepared from galls (excrescence produced on plants when punctured by insects) of various species of *Quercus* (Oak) and *Rhus* (sumach). The tannin content of these varies from 50-70 per cent. The galls are exposed to moist air for some time, when they undergo fermentation. They are then powdered and extracted with warm water (50-60°). The filtered solution is agitated for some hours with one-quarter of its volume of ether. After a week, the aqueous layer is separated, and the dissolved ether distilled over. It is then concentrated to a syrupy consistency and dried in thin films, on steam-heated plates or cylinders (Denston, A Text book of Pharmacognosy, 380). B. P. specifies that tannic acid, when dried at 100°, should lose not less than 6 per cent. and not more than 12 per cent. of its wt., and should not yield more than 9.2 per cent. of ash. Limits are also set for gums, dextrin, sugars and salts.

Tannic acid is now seldom given internally as it may interfere with gastric digestion. Its principal use is in the treatment of burns. Originally, a freshly prepared 2.5 per cent. aqueous solution was used, but recently it has been found that a strong solution (20 per cent.) containing also a little of acriflavin (0.1 per cent.) gives better results. Tannic acid jellies, used for burns and scalds, usually contain 5 per cent. of tannic acid in tragacanth together with antiseptics. A 15 per cent. solution of tannic acid in glycerine is beneficial in follicular tonsillitis.

During the last War, the Govt. Medical Stores and some pharmaceutical concerns in India prepared tannic acid required for military hospitals from myrobalans (*Terminalia chebula*, q. v.), and from imported galls.

The chief difficulty in extracting tannic acid from the commoner tannin-bearing materials, such as myrobalans, divi divi and sumach, is the removal of the high proportion of colouring matters and soluble non-tannins which occur along with it. These may be extracted with alcohol or acetone. From the residue tannic acid is precipitated out as its lead salt, and regenerated by means of hydrogensulphide.

Tartaric Acid

Tartaric acid, $C_4H_6O_6$, occurs in the form of colourless crystals (m. p., 170°), readily soluble in water. The natural acid is dextro-rotatory, and occurs in several fruits, either in the free state or in the form of acid potassium tartrate or calcium tartrate.

The acid is mainly used in the preparation of effervescent salines and beverages, in baking powders, in the textile industry (mordant), and in photography. Some of the salts, prepared from the acid, also find application in industries and analytical processes.

Tartaric acid is a by-product in the preparation of wine from grapes. Crude argol, which separates out during the fermentation of grape juice, contains 60-75 per cent. of potassium hydrogen tartrate. It is boiled with dil. hydrochloric acid and neutralized with milk of lime when calcium tartrate separates out. This is filtered, washed and decomposed by dil. sulphuric acid. Tartaric acid crystallizes out when the solution is filtered and concentrated in vacuum pans.

Tartaric acid is mainly prepared in Spain and Italy. During the quinquennium ending '38-39, the average annual imports into India amounted to about 120 tons, valued at Rs. 1.5 lakhs.

Tartaric acid occurs in the pulp of the fruits of tamarind tree (*Tamarindus indicus*), to the extent of 12.5-15 per cent., nearly half of it in the form of potassium hydrogen tartrate. The chief difficulty in the extraction of the acid from this is the formation of a gelatinous or slimy mass when the pulp is boiled with water. This cannot be easily separated by filtration. Sudborough and Vridhachalam (*J. Indian Inst. Sci.*, 1920-21, **3**, 61) have shown that if the pulp is autoclaved with water at 160° for one hr., the acid can be prepared by a method similar to the one used for its recovery from wine lees. The yield of free acid is about 6 per cent. on the weight of pulp, and of potassium hydrogen tartrate, 1.7 per cent. According to Marsden (*ib.*, 1922, **5**, 157), fermentation of pulp before autoclaving gives slightly higher yields.

TARTRATES

Potassium hydrogen tartrate, also known as cream of tartar, is obtained by the purification of argol. It is used in preparing baking powder. When neutralized with sodium carbonate, it yields potassium sodium tartrate, known as Rochelle salt. Rochelle salt is used as a mild purgative, and is one of the constituents of Seidlitz powder. Potassium antimonyl tartrate, "tartar emetic," is prepared by treating potassium acid tartrate with antimony trioxide. It is not now used as an emetic, but has been found valuable in the treatment of certain tropical diseases, such as leishmaniasis, filariasis, etc. It is also used in the textile industry as a mordant.

EXPORTS OF SOME ACIDS FROM THE U. K. TO INDIA*

Year	Formic acid		Acetyl salicylic acid		Salicylic acid	
	Cwt.	£	Cwt.	£	Cwt.	£
'40	106	329	2,328	81,875	1.378	14,963
'41	132	633	1,300	34,042	4,059	44,988
'42	n. a.		1,115	25,970	2,312	27,083
'43	241	1,123	1,922	61,069	4,000	50,983
'44	1,212	5,728	1,197	37,366	3,041	43,003
'45	1,070	4,976	878	38,292	626	8,548

* *Tr. U. K.*, III.

ADHESIVES

Adhesives are extensively used in a large number of industries for bonding surfaces. Natural adhesives include vegetable gums and resins, starches and dextrins, vegetable proteins, glue and gelatin, blood albumen, casein, etc. Shellac and rubber are also used for making adhesives.

Gum adhesives are extensively used in India mainly in the paper trade, in calico printing, and in distempers and white washes. These are made from water-soluble gums, like gum arabic, babul gum, etc. For ordinary purposes, a solution of the gum in 2-3 parts of its weight of water is found satisfactory, and often 8-10 per cent. of glycerine is added, to avoid too rapid hardening of the gum film and to prevent the brittleness of the dried gum and filler. Such adhesives are stable and sticky, and pale in colour. They spread easily and dry quickly.

Starch adhesives are relatively cheap and are extensively used for sizing and finishing textiles and paper, in calico printing, and in various other industries. The simplest type of starch adhesive is prepared by boiling starch with water and adding a little copper sulphate to make it insect-proof. It is extensively used in bookbinding as a general adhesive. When alkali is slowly run into a thin suspension of starch in water and well-stirred, a clear jelly of considerable strength is formed. This is used in making wood or cardboard boxes. Starches gelatinized by concentrated solutions of certain salts, like the chlorides of calcium, magnesium and zinc, are commonly used in office work.

Dextrins, also known as vegetable gum, starch gum, British gum, gommaline, etc., are made from starches by the action of heat, acids or diastase. When dissolved in water they give better adhesives than starches. Sometimes salts like sodium ammonium phosphate are added to make the dried films elastic. Dextrin adhesives are extensively used in postage stamps, stationery, paper-containers, and in labelling.

Glue (q. v.), prepared from slaughter-house wastes, is widely used in the wood, paper and textile industries, and also in the manufacture of abrasive paper and cloth.

OTHER ORGANIC ACIDS

Acid	Properties	Occurrence	Preparation	Uses
Benzoic, $C_7H_6O_2$	Long feathery needles, colourless and odourless; m. p., 121° (sublimes); soluble in boiling water, and in alcohol, ether, etc.	In several resins and balsams, especially in gum benzoin.	By sublimation from gum benzoin. Technically from toluene.	In medicine (sodium salt); antiseptic; food preservative (0.1%). Dyes, flavours and perfumes (esters); flavouring tobacco.
Formic, CH_2O_2	Colourless, pungent and corrosive liquid; b.p., 100.8°. Fumes, strong acid; miscible with water and alcohol; powerful reducing properties.	Sting of ants, bees and wasps, and also in some plants.	By the action of conc. sulphuric acid on sodium formate (*vide* Oxalic acid). Sold in concentrations, 75–90%.	In dyeing cotton and wool; in tanning for deliming hides; in silvering glass; antiseptic and preservative.
Malic, $C_4H_6O_5$	Colourless deliquescent crystals; m.p., 100°. Soluble in water and alcohol. Natural acid, laevo rotatory. Calcium salt soluble in water.	With citric acid in several unripe fruits, especially apples and mountain-ash berries (*Sorbus aucuparia* Linn.).	From mountain ash berries; hydration of maleic acid formed by the catalytic oxidation of benzene.	Medicinal; food acidulant.
Salicylic, $C_7H_6O_3$	Colourless needles, m. p., 157°; soluble in hot water, alcohol and ether.	In the form of esters in several essential oils; methyl ester in the oil of wintergreen.	From naturally occurring esters. By treating sodium phenate with CO_2 at ordinary temp., and later heating the compound formed to 120°–140°. Obtained on acidifying the salt with mineral acid.	Antiseptic and preservative; sodium salt in acute rheumatism.
Acetyl salicylic, $C_9H_8O_4$ (Aspirin)	Colourless and odourless crystalline powder; m. p., 135°–138°. Very slightly soluble in water; soluble in alcohol and ether. Gradually decomposes in moist air liberating acetic acid.		By the acetylation of salicylic acid.	Medicinal—analgesic, antipyretic and antirheumatic.

IMPORTS OF ACIDS INTO INDIA

(Qty. in cwt. and val. in thousand rupees)

Annual av. in the quinquennium ending in:	Hydrochloric acid		Nitric acid		Sulphuric acid		Acetic acid		Citric acid	
	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.
'38—39	752	17.1	2866	46.8	3495	31.0	5770	113	2483	133
'43—44	228	8.8	478	10.9	1753	21.1	10127	836	2841	268
In '44—45	40	4.5	27	3.4	38	13.3	16850	1255	4163	573
„ '45—46	62	5.3	44	4.0	93	6.6	6657	550	4129	482

Annual av. in the quinquennium ending in:	Oxalic acid		Tartaric acid		Stearic acid		Other acids	
	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.
'38—39	3134	105	2382	151				
'43—44	1230	83	977	164	7728	291	19420	1030
In '44—45	541	35	1342	397	2937	238	33038	2424
„ '45—46	2072	140	393	122	9154	511	8366	747

Casein cements are water-proof and are largely used in the manufacture of plywood for tea-chests and other purposes. Lactic casein is the only type at present manufactured in India, but rennet casein is more suitable for adhesive purposes. The simplest casein adhesive is made from casein and caustic soda, but it is not water-proof. The addition of calcium hydroxide converts sodium caseinate into calcium caseinate and renders the adhesive water-proof. Barium and magnesium hydroxide may also be used in place of lime. The working life of these cements is due to the alkali. Adhesives having a good working life and water resistance can be prepared by adjusting the proportion of lime to caustic soda. These are suitable for wet-mix only.

A suitable composition for casein cement has recently been developed at the Forest Research Institute. 100 parts of casein in 200 parts of water are added to a solution of 32 parts of lime in 100 parts of water. To this mixture is added 2 parts of sodium silicate (40° Be .) followed by a solution of 2 parts of copper sulphate in 30 parts of water (*Indian For. Bull.*, *New Series*, No. 116, 1945, 12).

In the manufacture of dry casein cements, alkali is introduced in the form of the sodium salt of a weak acid (fluoride, phosphate, borate, etc.) with or without the addition of an equivalent proportion of slaked lime. Sodium silicate may also be used, but in this case the ingredients are mixed just before use. This salt lengthens the working life of the adhesive.

Shellac adhesives consist generally of three types : (*a*) cements in solid form for melt or hot spray application, (*b*) adhesive pastes, and (*c*) glues and varnishes. The first type is prepared by melting and mixing orange shellac and hydrolysed lac at 110-120°, to which are added fillers, such as mica, slate dust, carbon black, etc. Adhesive pastes are made by mixing hydrolysed lac and fillers with cold or warm water in a putty mill. Small amounts of malic and tartaric acids are added as adhesion promoters. The last type consists of solutions of orange shellac in methylated spirits with fillers and adhesion promoters (*vide* Murthy, *Plastics*, 1945, **9**, 585, & 624).

Shellac adhesives possess high bond strength to smooth surface, remain unaffected by ageing, and have a high resistance to attack by transformer oil and petroleum hydrocarbons. The extensive use of these adhesives is, however, limited by the brittleness, the low softening point, and the comparatively poor water resistance of shellac. These deficiencies, however, may be overcome by suitable modifications of the adhesives.

In India, the use of shellac adhesives has greatly developed during World War II in the manufacture of various laminated products from jute, paper, fabric, etc. Shellac is also used in the manufacture of jute-fabric-laminates, called 'Jutlac'. Molten shellac is applied to the laminate surface in a continuous manner with the help of hot rollers. An alcoholic solution of the resins, obtained by modifications of shellac with formaldehyde and urea, or formaldehyde and melamine, have also been tried at the Lac Research Institute for the preparation of laminated board. The boards thus prepared are reported to possess remarkable mechanical and shock-resisting properties, in addition to low water absorption (*J. sci. industr. Res.*, 1946, **4**, 396).

Grinding wheels are manufactured by the incorporation of abrasive powders in molten lac and shaping the composition while still hot and plastic. Some coated abrasives are also made with shellac adhesives. Shellac is the main constituent of sealing wax, and cements and adhesives for joining smooth surfaces, like glass, mica, metal plates, etc. Shellac adhesives are also used in India in the manufacture of various micanite products.

Rubber cements are of two types : the solvent-rubber type and the latex type. The former is made by dissolving pale crepe or smoked sheet rubber in solvent naphtha, with or without the addition of benzed or carbon tetrachloride. The adhesive produced is tacky, viscous, and fast drying, but it is not very strong and is, besides, inflammable. These cements are now produced for use in India in the rubber industry, including the manufacture of rubber soled canvas shoes. Messrs. The Dunlop Rubber Co. (India) Ltd. produce annually 45,000 gallons of rubber solution for cycles and motors, 15,000 gallons of vulcanizing solution, and 250 gallons of upholstery cement and solution.

The latex type is growing in importance, especially owing to its water resistance and good flexibility. Ammonia is added as a stabiliser and this type of adhesive is often compounded with other glues to increase their adhesive properties.

In the manufacture of black adhesive tapes for electrical insulators, suitable cotton cloth is dipped in a solution of rubber latex and bitumen in mineral oil, dried, rolled and cut into various sizes. Encouraged by the Dep. of Supply, two firms started production in Calcutta in 1943, and their output in the following year was estimated to be about 40 tons (valued at Rs. 2.8 lakhs), a quantity sufficient to meet the peace-time requirements of India (Thomas, Rep. Metall. & Engng. Industr., 1944, 68).

During the War ('39-45) due to shortage of casein, certain adhesives were developed at the Forest Research Institute, Dehra-Dun, from some oil-seed cakes and their proteins, cereals, etc. to meet the increased demands of the plywood industry (*Indian For. Leafls.*, Nos. 15, 16, 40, 52, 58, 59 and 62). These were also used in the textile and paper industries. An adhesive prepared by suitably mixing groundnut protein, lime, sodium silicate, and copper sulphate was found to possess good dry strength and satisfactory water resistance (*ib.*, No. 15).

Synthetic adhesives prepared from synthetic resins are of recent origin. Of these, adhesives made from phenol-formaldehyde and urea-formaldehyde resin are the most important. The uniform quality and composition of synthetic adhesives enable a standardized gluing technique. They are, besides, easily modified to meet the special requirements of any particular industry. They give moisture-proof joints, resistant to chemicals, fungi, and insect attacks. These are greatly in demand in aircraft, shipbuilding and allied industries. In India, small quantities of imported thermoplastic synthetic products are used for producing special types of plywood.

AERATED WATERS

Aerated waters consist of carbonated water, containing small amounts of mineral salts. Usually, the chlorides and sulphates of sodium potassium, magnesium and calcium, sodium carbonate and phosphate, and sometimes also lithium chloride are used. Soft drinks, such as lemonade, orange crush, ginger beer, kola, and raspberry, are prepared by carbonating sweetened waters, suitably flavoured and coloured.

The water to be used, unless it is already filtered and treated, as from a city supply pipe, should be purified and chlorinated. A hard water, especially one owing its hardness to calcium sulphate, is best suited to soda water manufacture. The addition of certain salts—soda salts—helps in the retention of carbon dioxide in the form of bicarbonates. Soft water is used for sweet drinks. This enables proper blending of the constituents.

The larger factories produce pure carbon dioxide in generators by the action of sulphuric acid on sodium bicarbonate. Small concerns make use of steel cylinders of compressed gas. A 22 lb. cylinder is sufficient to carbonate about 100 doz. bottles of soda water and about 150 doz. bottles of sweet drinks. The gas obtained from sodium carbonate, being purer, gives a better taste.

Cane sugar forms the basis of all sweet drinks. It is partially replaced by saccharine, which unlike sugar is non-fermentable, and is more economical. Small quantities of glucose and golden syrup, and a little citric acid are also added to improve taste. The other acids thus used are tartaric, phosphoric, lactic or malic acids ; blends of two or more acids may also be employed. The acids impart characteristic taste and 'sharpness' to drinks. They should be of edible grade, free from metallic and arsenical contaminations.

Essences and essential oils, and sometimes also alcoholic extracts and fruit concentrates are used to flavour the drinks. Some aerated water colour powders of doubtful quality are being manufactured at Amritsar, from imported dyes and desiccated sodium sulphate (Indian Tariff Bd. Rep., Butter Colour and Aerated Water Powder Colour Industry, 1946).

Several varieties of bottles have been used in the industry. Codd's marble stoppered bottles were formerly used extensively, but these have been replaced now by plain crown-corked bottles, which are more easily cleaned. These are made of strong glass, and can withstand high pressure, and the cork consists of a lacquered tin-plate disc with a corrugated edge for the grip. It is lined with cork, and has an oil-paper intercept to prevent the liquid from touching the metal. The bottle is sealed by pressing down the crown-cork into the boss on its neck. The average annual imports of soda water bottles during the quinquennium ending '38-39 were 35,950 gross, valued at Rs. 6 lakhs.

In the manufacture of aerated water, all forms of contamination—chemical, metallic and bacteriological—must be scrupulously avoided. Samples from water mains, soda tank, lemonade tank, etc., should be periodically tested for chemical and bacteriological purity. Metallic contaminations are avoided by tinning all the cylinders and using only pipes made of tin.

The water used, after being chlorinated and mixed with salts, is chilled to almost freezing temperature by the expansion of carbon dioxide, and is then carbonated under pressure. In the 'Riley' patent automatic carbonator or soda water compressor, chilled water is pumped to the top of the cylinder. It is sprayed down when it dissolves carbon dioxide which is fed from the bottom. The pressure inside the carbonating cylinder is 125-150 lb./sq. in. for soda water, and 75-100 lb./sq. in. for sweet drinks.

The carbonated water is pressure-filled, prior to bottling in an automatic rotary multiple-head filling machine. In these machines, an upper cylinder is charged with the carbonated liquid, and bottles are fed underneath, on a rotating platform to openings which fit tight into the bottle mouths. The air in the bottle is expelled through a valve into the top of the feeding cylinder, and is discharged automatically through a valve. The filling is done under a fairly low pressure without much loss of gas. The bottles, after being filled, are automatically fed to the capping side, where they are crown-corked.

For the manufacture of sweet drinks, syrup is prepared by boiling sugar (55-65 per cent.) with water after the addition of small quantities of saccharine and golden syrup. It is then cooled and mixed with acids, flavours, colours, etc. The flavoured syrup is fed to a syruping unit, fitted to the automatic machine, and blended (*ca.* 1oz. per bottle) with carbonated water during filling.

In smaller factories, water is cooled by passing it through a coil immersed in ice.

Carbon dioxide from a cylinder, after being filtered through a solution of potassium permanganate, is forced under pressure into the carbonator. A rotary machine is used for filling, and the carbonated water is introduced into the bottle in successive stages, the air being released through a valve. The filled bottles are then capped in a separate machine. A single multi-purpose hand-operated machine is employed in very small concerns.

It is essential that during filling, air is expelled completely from the bottle. Otherwise, being much less soluble in water than carbon dioxide, air will rush out when the bottle is opened, with the drink becoming flat soon.

Bottle-washing is of the utmost importance in aerated water factories. In larger factories, bottles are cleaned in automatic power-driven machines using a good caustic detergent. These detergents generally contain sodium carbonate, silicate, and hydroxide, and trisodium phosphate. In smaller concerns, bottles are soaked in a solution of washing soda, brushed, and treated with a solution of potassium permanganate to disinfect them and finally washed with fresh water.

Automatic machines capable of turning out 120-140 doz. bottles per hr., are imported, mostly from the U. K., and the average annual imports of soda water machines during the quinquennium ending '38-39 were valued at Rs. 36,500. Smaller machines of capacity 3-80 doz. bottles per hr. are made in India and their prices vary from Rs. 300 to Rs. 3,500.

Aerated water factories are found in almost all the big cities. A few large concerns in Calcutta, Bombay and Madras produce over 10,000 bottles per day, and the largest of these has an output of about 72,000 bottles per day. Besides these, there are numerous small concerns, both in cities and in smaller towns, turning out dozens of bottles per day. In general, more than 50 per cent. of the output consists of soda water, and the rest, of sweet drinks. Production is easily switched over from one to the other according to demand.

The output is generally controlled to meet immediate local demand. Hence, in this industry the problem of spoilage is not serious. The spoilage, when it occurs, is mainly due to yeasts, since acidity inhibits most types of bacteria. The source of these yeasts are sugar syrups when not sterilised, contaminated pipe lines, and improperly washed bottles. Besides, light and chlorine bring about certain chemical changes, if the water used has been chlorinated (von Loesecke, 386). Long storage leads to flatness, owing to escape of gas from imperfectly capped bottles.

AGARBATTIS

The burning of incense in religious and social functions has been practised in India since early times. *Dhup*, an aromatic powder or paste, is burnt in Indian homes as a fragrant fumigant, and is reputed to possess insecticidal and antiseptic properties. *Agarbattis*, also known as *udbattis*, similar to joss-sticks, are a development of *dhup*.

Several aromatic woods, roots, barks, etc., essential oils and synthetic aromatics, resins and balsams, are used in the preparation of *agarbattis*.

PRINCIPAL INGREDIENTS USED IN THE PREPARATION OF *AGARBATTIS*

Woods	Agar, black (*Aquilaria agallocha*) Sandal (*Santalum album*)
Roots	Costus (*Saussurea lappa*) *Kapur-kachri* (*Hedychium spicatum*) *Sumbal* (*Nardostachys jatamansi*) Vetiver (*Vetiveria zizanioides*)
Barks	Cassia (*Cinnamomum cassia*) Cinnamon (*Cinnamomum zeylanicum*)

Leaves	Patchouli (*Pogostemon heyneanus*) Himalayan silver fir (*Abies* spp.) Marjoram (*Origanum majorana*)
Flowers ..	Rose buds (*Rosa* spp.) Champak (*Michelia champaka*) Cloves (*Eugenia caryophyllata*)
Seeds	Cardamom (*Elettaria cardamomum*) Mace (*Myristica fragrans*)
Gums and resins	Myrrh (*Commiphora* spp.) Olibanum (*Boswellia carterii*) Benzoin (*Styrax benzoin* Dryand.) Storax (*Liquidambar orientalis* Mill.) *Halmaddi* (*Ailanthus malabaricum*)
Miscellaneous ..	Charcoal Saltpetre Colours, etc.
Filler	'Wood gum,' *Maida ki lakdi* (wood of *Litsaea sebifera*)

Agarbattis are usually made in the form of sticks, varying in length from $4\frac{1}{2}$-16″, and in diameter, from $^{1}/_{16}$-1″. The purified resins, essential oils and fixatives are mixed with powdered fragrant woods, other aromatics, and water, and ground into a fine paste. Sometimes aniline colours are also added. 'Wood gum' is then mixed with the paste and kneaded. Usually, the raw materials are powdered and ground by manual appliances. Some concerns also use mills. The resulting hard paste is coated on bamboo sticks, cut into thin lengths of the required size, and rolled by hand on a smooth plank to suitable thickness. During rolling, colours, sandalwood dust, fumigating compounds, etc., are added to give them even finish and appearance. The rolled sticks are dried in shade, and packed in small bundles.

TYPICAL COMPOSITION OF *AGARBATTI* OF MEDIUM QUALITY

	(Per cent.)
Sandalwood	30
Black agar	20
Vetiver	5
Kapur-kachri	5
Leaves and flowers	10
Olibanum or myrrh	20
Charcoal and other ingredients ..	10

To this add 25-35 per cent. of 'wood gum' powder of not less than 80 mesh.

Agarbattis are obtainable in different colours, and with different perfumes. The burning time of an *agarbatti* varies from 15 min. to 3 hrs., according to quality and size. *Agarbatti* is also obtainable in other forms, such as, *dashang* (sticky paste or powder), *deep* (cones) and *dhup*, tablets, etc.

Agarbatti-making is a cottage industry in Mysore State, and Madras and Bombay Provinces. There are about 200 concerns, more than half of which are located in Mysore State, chiefly in Bangalore. Mysore City, Madras City, Poona, Pandharpur and Tanjore are the other prominent centres of production. Nearly 10 thousand skilled workers, mostly women, are employed in the industry.

About 75 per cent. of the *agarbattis* manufactured are of cheap quality containing only charcoal powder or low quality sandal wood powder with a mixture of 50 per cent. of 'wood gum' powder. Cheap perfumes are used to give them a top note. In superior varieties, essential oils, purified resins, natural fixatives like amber, musk and civet are used along with synthetic aromatics. Absolutes are used in the costlier types. Before the last War, *agarbattis* of medium quality used to be sold at Re. 1 to Rs. 1-8 per lb. and now they are sold at Rs. 5 to Rs. 6, but the selling price of high class *agarbattis* has risen from Rs. 40 per lb. to only Rs. 60.

Agarbattis are used by many communities in India, Ceylon, Burma, and by Indians residing in Africa, Malay States, Dutch East Indies, etc. Before the War, there was also a small demand for them in the U. K., the U. S. A. and Canada.

AGRICULTURAL IMPLEMENTS

Agricultural implements include ploughs, harrows, clod-crushers, etc. In India, the farmer himself makes most of these implements, out of locally available timbers, sometimes with the help of the village blacksmith. The strongest, toughest and hardest woods are selected, and the following is a list of such woods : *Acacia arabica, Acacia catechu, Anogeissus latifolia, Cassia fistula, Chloroxylon swietenia, Dalbergia sissoo, Diospyros melanoxylon, Mesua ferrea, Ougeinia dalbergioides, Prosopis spicigera, Pterocarpus* spp., *Quercus* spp., *Schleichera trijuga, Shorea robusta, Tectona grandis, Xylia* spp., and *Zizyphus jujuba* (Trotter, 1940, 171 ; 1944, 192).

The demand for agricultural implements made of iron increased greatly after the first World War. The Agrico Ltd., the first, and even now the only modern factory for mass production of edge tools, was established in '22. By about '39, there were nearly ten large concerns in India producing agricultural implements, and the production of pick-axes, shovels, hoes, *powrahs*, *kodalies*, etc., was large enough to meet a substantial portion of India's demand. The implements now made in India are ploughs, harrows, sickles, hoes, shovels, pick-axes, digging forks, *kodaly* forks, *mamty* forks, felling-axes, pruning knives, etc. Out of about 200 varieties of edge tools made in this factory, various kinds of picks, hoes and felling axes are extensively used by agriculturists.

The factory gets its steel supplies from the Steel Works at Jamshedpur, who roll them in sections suitable for various tools. The steel used is of high carbon quality (carbon content of steel : for picks, 0.50-0.60 ; for hoes, 0.45-0.60 ; octagons, 0.75-0.85 ; squares, 0.45-0.55 ; and flats, 0.60-0.75 per cent.). Pick-axes (*gaintees*) are made out of billets $1\frac{3}{4}'' \times 1''$, $2\frac{1}{2}'' \times 1\frac{1}{4}''$, and $2\frac{3}{4}'' \times 1\frac{1}{4}''$. *Powrahs* are made out of hoe bars of $\frac{1}{2}''$, $^{9}/_{16}''$ and $^{5}/_{8}''$ thickness and $8\frac{1}{2}''$, width. Hammers of various weights and types are made out of square sections of steel bars. Felling axes, crow-bars, chisels and meat choppers are made out of flats and octagons. The village blacksmiths are unable to use quality steel owing to its high cost, and invariably use scrap.

Machinery required for the manufacture include forging machinery, consisting of pneumatic hammers, spring hammers, and the usual smithy tools and accessories, grinding and polishing machines, electric furnaces for tempering, welding plant, machine shop equipment, etc.

MAKING A PICK

(*Courtesy of the Supt., Agrico Factory, Jamshedpur*)

Picks are made out of pick bars which are first sheared into pieces of suitable weight and length. The blanks are heated to about 1000° and the eye is first forged on a 200 ton Bliss electrically driven press, fitted with a set of eye forming and trimming dies. The first operation punch imparts the rough shape of the eye to the blank and draws the metal for forming the eye under the second operation punch. The fins and slugs formed at the top and bottom of the eye are removed by trimming. The eyes are then reheated and both ends elongated according to the shape required. About $1\frac{1}{2}$-$2''$ of the flat and pointed ends of the picks are ground to give sharp edges and point. To ensure long life, about $2''$ of both ends are hardened and tempered, and the hardened ends polished. Finished picks are finally varnished or painted.

Powrahs or *kodalis* are made out of hoe bars $\frac{1}{2}''$ wide and $\frac{1}{2}$—$^{5}/_{8}''$ thick. The blanks are cut on a shearing machine according to the weight of the *powrah*. They are heated to 1000° and rolled one by one, under a pair of reciprocating rolls, to the required length. An eye is then punched in the blank in a 7 Cam press, and superfluous metal trimmed. The *powrah* is then curved and stamped. *Powrahs* so forged are sent to the grinding machines where about 2″ of the edge portion and the burrs on the sides are ground. The edges are then hardened, tested, varnished and painted.

Felling axes are forged out of flats (3¾″ x 1″) which are first sheared to the required weight. The blanks are heated to 1000°, and the eye formed under a press using suitable dies. The taper on the section is obtained by flattening out the metal under a plating hammer. Finally, these forgings are finished by hand to remove unevenness of surface and of the eyes. The forks are then sent to the grinding section for grinding the edge sharp and for removing burrs. They are finally hardened, tested, polished, and varnished.

Implements, such as, tea-garden tools, shovels, and knives, are not yet being made on a large scale.

A large portion of the country's requirements of agricultural tools is met by Agrico. The production of a lakh of tools requires, on an average, 350 tons of steel bars and sections. Before the last War, the factory was using 5,000 tons of steel annually, producing about 12 lakhs of tools. During the War, this factory, working three shifts a day, produced annually 31.2 lakhs of tools from 10,000 tons of steel. Agrico's entire production of pick-axes (90,000 per month) was reserved for the Supply Dep., but the production of hoes (140,000 per month) was not controlled except for the supply of steel. Skilled and unskilled labour necessary for producing a lakh of tools per month is about 300 men per day.

The *desi* plough consists of a wooden beam, a wooden handle, and a standard fitted with an iron piece at its end, which acts as the cutting edge. The plough is of the ripping type; it breaks the soil without inverting it, and makes a furrow about 4½″ deep, and 2-3″ wide.

Iron ploughs were put on the market in 1904 by Messrs. Kirloskar Bros. (Kirloskarvadi, Satara Dist.), but these did not sell for a few years owing to their cost and the conservatism of the farmer. They are now being manufactured by several firms, the most important of them still being Messrs. Kirloskar Bros. A number of types have been developed for different soils, and these require 1-4 pairs of bullocks according to size and weight. The furrow capacity varies from 3″-16″ in depth, and 4″-16″ in width. Light ploughs are used for light soils and heavier types for irrigated land and black-cotton soil.

Steel ploughs are usually of mould-board type. The share and the mould-board are its most important parts. The former is generally made of high carbon steel (carbon, 0.5-0.6 per cent.) and its cutting edges should be thoroughly chilled to a depth of about $^1/_8$″ to make them hard and wear-resistant. The shares are also polished to lessen friction. The mould-board which turns up the soil is also made of steel (carbon, 0.3 per cent.) and is polished. The share and the mould-board are fitted to the body of the plough, built of mild steel flats and rounds.

Other agricultural implements and machinery made by Indian manufacturers are disc harrows, scrapers, hand cultivators, sugar cane crushers, decorticators, chaff cutters, etc. Recently the Aircraft Factory at Ghorpuri, near Poona, has been leased by the Government to Messrs. Pashabhai Patel & Co., for a year, for the manufacture of power-driven ploughs, harrows, etc., to be worked with tractors purchased from British and American war surpluses (*East Economist*, 1946, **7**, 10).

AVERAGE ANNUAL IMPORTS OF AGRICULTURAL IMPLEMENTS AND MACHINERY

(Lakhs of Rs.)

In quinquennium ending :	Implements	Agricultural machinery			
		Ploughs & parts	Tractors & parts	Other sorts	Total
„ '33—34	8.1	1.3	5.1	2.8	9.2
„ '38—39	2.2	1.7	5.6	4.3	11.6
„ '43—44	2.4	1.2	13.4	1.8	16.4
In '44—45	2.3	0.3	8.3	1.1	9.6
„ '45—46	2.3	1.1	22.5	3.2	26.8

During the quinquennium ending '38-39, the U. K. supplied 65 per cent. of agricultural implements, and 56 per cent. of ploughs, imported into India.

ANNUAL EXPORTS OF SOME AGRICULTURAL IMPLEMENTS FROM THE U. K. TO INDIA

(No. in thousands and val. in thousand pounds)

	In quinquennium ending '39 :		In quinquennium ending '44 :	
	No.	Val.	No.	Val.
Forks	29	5	16	3.0
Shovels and spades	182	13.5	69	7.5
Scythes and others	..	49.3	..	29.0
Ploughs ..	(28 tons)	2.9	..	..

*Tr. U. K., III.

AIRCRAFT

Aircraft manufacture is a highly specialized industry. It involves the use of more than 1,000 different types of raw materials, the most important of which are strong light alloys, such as aluminium and magnesium alloys and wood. Others are steel, nickel alloys, brass, rubber, fabric, tapes and cordage, plastics, dopes, adhesives, paper, paints and varnishes.

Over three-quarters of the weight of the frame of a modern aircraft consists of aluminium alloys (*vide* Aluminium). These alloys combine lightness with extraordinary strength and rigidity. Aluminium casting alloys, containing zinc and copper, are used for general casting work including the aero-engine (cylinder heads, pistons, crankcases, etc.). The Rolls-Royce Merlin XX aero-engine contains 43.6 per cent. by weight of aluminium alloys. Wrought aluminium alloys, of the well-known duralumin type, are used exclusively in the form of sheets, strips, girders, rivets, etc., in the construction of aircraft framework such as ribs, beams, wing skins, fuselages, etc., where a metal with very high strength-weight ratio is required. Duralumin has roughly the same strength as mild steel and a third of its weight. Blades of most metal propellers are made of aluminium alloy forgings. Besides these, many complex aluminium alloys, such as the R. R. alloys, are used for forged pistons, and commercially pure aluminium sheet for non-structural parts (cowlings, wings, tanks, etc.).

During the last War, the Indian Aluminium Co. Ltd., Belur, installed a plant to produce about 20 tons of duralumin sheets per month. The Aluminium Mfg. Co., Calcutta, have done considerable work on the casting of aluminium alloys, and 3 or 4 firms including the Hindustan Aircraft Ltd. are also capable of doing this work. Aluminium wire is being made in India, and some Ordnance Factories have equipment for extrusion and forging work.

Magnesium alloys, containing up to about 11 per cent. aluminium and small amounts of manganese and zinc are the lightest structural alloys known, being two-thirds the weight of aluminium. They possess excellent machinability, toughness and fatigue endurance, and have a high strength-weight ratio. These are extensively used in aircraft engine castings, instrument housings, landing wheels, under-carriage members, miscellaneous structural parts, forged air-screws, petrol and oil tanks, and interior fittings, etc.

Other metallic parts are made of alloy steels and copper alloys. The use of stainless steel is increasing rapidly owing to its great strength, extremely high strength-weight ratio, high resistance to corrosion and adaptability to production methods. Pure copper is also used chiefly in the form of tubing for fuel and oil lines, ignition wire and other essential parts.

Next to light alloys, timber is the most important raw material used. Aircraft timber must be of the highest quality and should conform to very strict specifications. It should be perfectly straight-grained, without knots or defects, and should be very carefully selected and kiln-dried. Moisture content, on which depends the strength of the wood, should be properly regulated. Special aeronautical grades of birch (*Betula* spp.), balsa (*Ochroma lagopus* Sw.), Sitka spruce [*Picea sitchensis* (Bong.) Carr.], Douglas fir, etc., which combine toughness and lightness, are used for general structural work, like spars, ribs, longerons, etc., for high quality plywood, for propellers, for linings, and for targets and model aircraft. For the main members, *viz.*, spars supporting the wings, longerons supporting the fuselage and tail members, only the best selected North American Sitka spruce is used. This variety is preferred to best alloy steel and duralumin owing to its higher strength-weight ratio and also because it can be obtained in clear, straight-grained pieces of large size and uniform texture.

Indian spruce (*Picea morinda*) and Indian fir (*Abies pindrow*) have been found to conform to aircraft specification for Grade A materials. Selected pieces from the Indian spruce are stronger than Sitka spruce in bending and compression, but slightly weaker in brittleness, and yield up to 10-12 ft. of aircraft quality timber. Indian spruce may be used in place of Sitka spruce, but very strict supervision is necessary during its felling and conversion. Considerable quantity of Grade B material can also be obtained from this timber. But it is difficult to obtain timber of sufficient length, completely devoid of knots and defects, and hence it cannot be used for the construction of spars for wings. Investigations at the Forest Research Institute have proved the suitability of certain Indian light hardwoods, such as *Michelia excelsa*, *Polyalthia fragrans*, *Michelia champaca*, *Canarium euphyllum* and *Phoebe goalparensis* for this purpose. The first two timbers are the nearest substitutes for spruce ; the next two woods are good for Grade B material, and, if properly selected, also for Grade A material. *Phoebe goalparensis* is good, but it is somewhat heavier than Sitka spruce.

For plywood required for covering body framework and wing surface, special aircraft quality timber such as birch, and maple (*Acer* spp.), is used in Europe. Indian substitutes are *Dichopsis elliptica*, *Zanthoxylum rhetsa* and *Dalbergia latifolia*. Other woods mentioned as probably suitable are *Polyalthia fragrans*, *Juglans regia*, *Phoebe goalparensis*, *Dalbergia sissoo*, *Machilus macrantha*, *Terminalia myriocarpa*, *Mangifera indica*, *Michelia* spp., *Chukrasia tabularis*, Himalayan maple (*Acer campbellii*), and *Dipterocarpus macrocarpus*. At present only two firms, one in the U. P., and the other in the South, are capable of manufacturing aircraft quality plywood.

Airscrews are generally made from laminated blocks made of walnut and mahogany. In many cases, compregnated wood is used. The best Indian timbers for this purpose are of *Pterocarpus dalbergioides*, *Artocarpus hirsuta*, *Chuckrasia tabularis*, *Michelia champaca* and *Phoebe goalparensis* (Trotter, 1940, 152 ; 1944, 189 ; *vide* also Limaye, *Indian For. Rec.*, *New Series*, *Util.*, 1942, **2**, 168).

Cotton fabric is used for covering fuselage wings and control surfaces, and tape for covering stitches and for reinforcing and binding. Dope which is applied to the outer fabric for tightening, strengthening, and waterproofing is a heavy solution made from cellulose nitrate or cellulose acetate base. The nitrate dope is generally used, but the acetate dope on account of its fire-proofing quality, is employed for the finishing coat.

There are two types of aircraft manufacture : factories which turn out complete planes, and assembly plants, building planes from ready-made units produced by others. Only very big concerns come under the first category, and the bulk of manufacturers belong to the second.

Mass production is not always possible in this industry owing to the small volume of turnover, and the great variety of models. Machines of huge size are built with a high degree of precision and workmanship. Manufacturers are reluctant to start mass production on account of frequent changes in design.

In the manufacture of an aircraft, designing is the first step, and this depends upon the purpose for which the machine is built. The main types are military planes, light commercial planes, private and business planes, and airline transport planes, and each of these groups is composed of numerous sub-types. For the present, in India, the Government intend to use foreign designs for the Air Force. These will be replaced later by designs developed locally.

The main parts of an aircraft are the wings, the fuselage, power plant including the engine, propeller, petrol and oil tanks, the tail group including the vertical fin, the rudder, stabilisers and elevators, the landing gear and all accessories. Each of these is assembled first, and during the final assembly the major components are put together, the order depending greatly upon the design.

Although three factories were set up at Bangalore, Barrackpore and Poona for the manufacture of aircraft during the last War, there was no production at the end of the war, and the future of the industry was uncertain. In '46, the Government of India requested the British Govt. to send a Mission to advise them on the establishment of an aircraft industry in India. On the recommendation of the Mission, the Government selected the Hindustan Aircraft Ltd., Bangalore, to form the nucleus of the industry (Rep. U.K. Aircraft Miss., 1946).

This factory was the first to be established in India (Dec. '40) under the stimulus of War, for assembling and ultimately for manufacturing aircraft. Its original capital of Rs. 40 lakhs was subscribed equally by the Govt. of Mysore and Mr. Walchand Hirachand. In Apr. '41, the Govt. of India became one of its shareholders and the capital was raised to Rs. 75 lakhs, held equally by the three partners. The factory was equipped largely with American plant and machinery.

The first Indian assembled aeroplane came off the production line in July '41, followed by the second in the next month. But with the intensification of war, the Govt. of India were obliged to assume full control of the factory by buying out Mr. Walchand Hirachand's interest, and by payment of a solatium of Rs. 12.5 lakhs to the Mysore Govt. for the duration of war. In '43, the war situation made further expansion necessary, and the factory was handed over to the United States Army Air Force under the Managing Agents agreement for servicing, repairing and overhauling of all American purchased aircraft, engines, and equipment used in India. The managing agency agreement between the U. S. Army Air Force and the Hindustan Aircraft Ltd. was terminated in Dec. '45. In Apr. '46, the position of the Mysore Govt. as an active partner was restored. It is now a private limited company, jointly owned by the Governments of India and Mysore, sharing the capital in the ratio, 2 : 1.

During the War, the factory suspended the manufacture of aircraft and switched over to the maintenance, overhaul and repair of aircraft engines, and accessories. All manufacturing jigs and fixtures, partially manufactured aircraft and components were scrapped, and the floors cleared for repair work on four major types of American aircraft : B-24 'Liberator' Bombers, B-25 'Mitchell' Bombers, Douglas C-47 (Dakota) Transports, and Catalina Flying Boats. Also many other types of aircraft, from the Flying Fortress Bomber to the Mosquito Fighter, were serviced. An Engine Division was established for the complete overhaul of Wright and Pratt & Whitney engines. An Accessories Division was set up to handle overhaul of radio, flight instruments, magnetos, starters, generators, batteries, and pumps. An interesting auxiliary programme was the construction of more than twenty-seven thousand 'droppable belly tanks' which were installed on fighter aircraft to increase their range, and jettisoned when empty.

The following statement gives a general idea of the amount of work accomplished during the War (Hindustan Aircraft) :

	No.
Cargo—C-47's (Dakotas) overhauled	406
Bombers—B-25 (Mitchells) twin-engined light bombers	374
B-24 (Liberators) four-engined heavy bombers	176
Catalinas twin-engined flying patrol boats	55
Aircraft engines	3,799
Auxiliary fuel tanks	21,491
Misc. aircraft	160
Spark plugs	765,978
Engine accessories and batteries	80,673
Radios	11,492
Rubber parts	19,831
Propellers	2,447
Propeller components	11,626
Instruments	63,139

At present, the factory acts mainly as overhauling, repairing, assembling and conversion depot for Civil Air Lines and the Air Force, and issues 'certificate of airworthiness,' and also manufactures some components and spare parts for use in repair work. The present (Apr. '47) output is the overhauling and repairing of 8-10 aircraft and 25 engines per month. So far (Apr. '47), about 80 aircraft and 80 engines have been completed. The Aircraft Miss. estimate that 20 per cent. of overhaul and repair work in respect of scheduled transport aircraft will flow to this company, which in terms of annual receipts are estimated at Rs. 6, 9, 12 and 15 lakhs, during the quinquennia ending '50, '55, '60, and '65 respectively. They also estimate that 25 per cent. of the work from hire and charter operations, 30 per cent. from private owners and 20 per cent. from flying clubs will come to the factory, which will bring the concern Rs. 6, 8, 12 and 15 lakhs respectively, during the four successive quinquennia.

Now the factory has been reorganised and the Company has taken up the production of Percival Prentice Trainers for the R. I. A. F. under an assistance arrangement with the Percival Aircraft Co., England. The Ministry of Defence have placed an initial order for 50 such aircraft. The cost of manufacturing a Percival Prentice aircraft has been estimated at Rs. 1.16 lakhs, excluding that of the engine.

The first few planes to be made at the Hindustan Aircraft Ltd. are expected to be ready by May '48, and these will be assembled from imported components. Gradually indigenous components will replace imported ones and the first aircraft to be manufactured using indigenous components is expected to be ready by Sept. '48. The programme is to assemble 15 from components and 5 from detailed parts, and to manufacture 30 from raw materials, before June '49. The development of engines is not likely to be taken up at present owing to the likelihood of their being superseded by internal combustion turbines or jets.

The Hindustan Aircraft Ltd. has also undertaken the manufacture of 100 improved type of third class railway coaches with steel panel for the Ministry of Railways, at a fixed price of Rs. 60,000 per coach. To meet this expanded programme, the company decided to increase its share capital from Rs. 75 lakhs to Rs. 175 lakhs.

From mid-'42 to early '43, the labour force of the factory increased from 3,500 to 13,500, and early in '45, well over 16,000 employees were on the rolls. Since the end of the War, there has been drastic retrenchment, and now with the exception of 23 British and American supervisory personnel, the staff consists entirely of Indians, composed of 2,341 daily labour, 1,187 monthly rated labour, and 63 officers and executives. The labour force discharged after the War, of whom about 60 per cent. are estimated to be available for re-employment, forms a valuable pool from which additional labour can be drawn, if required.

In Oct. '43, the Govt. of India also established a number of Civil Maintenance Units for the Air Force, under the Directorate-General Aircraft, to repair and maintain aircraft, aero-engines, propellers, instruments and other components. Salvage of serviceable or repairable parts from obsolete aircraft and recovery by electroplating, etc., was an important feature of their work. 18 Units were functioning in '44, and a separate Civil Maintenance Unit controlled by the Tata Aircraft, Barrackpore, was specially engaged on the assembly of aircraft from imported parts and its average monthly outturn rose to 70 aircraft.

Contracts were also placed with the Tata Aircraft and the Indian National Airways for the repairing and maintenance of planes. Three Tata Civil Maintenance Units commenced work early in '44. By the end of May '44, the Civil Repairing Organizations had repaired about 700 aircraft and 1,750 aero-engines, in addition to a large amount of aircraft modification and inspection work. The average monthly outturn of repair work of a few important items was 2,000 dash-board instruments, 3,000 magnetos, 1,500 replated accumulators and 200 wireless sets. The Mathematical Instruments Office, Calcutta, repaired more than 58,000 instruments.

In addition to repair and maintenance work, the Directorate also undertook the manufacture of aircraft equipment, and parts and spares for air frames and aero-engines. During '43, 13,270 different items, covering several large and small parts were manufactured in these factories. 10,000 aluminium and 5,000 plywood hurricane petrol tanks, and 3,000 Spitfire petrol tanks were completed, by Aug. '44.

The training of engineers, craftsmen and managerial staff for the Indian Aircraft Industry is very important and raises many problems, and the Hindustan Aircraft Ltd. will train its own personnel. The skill required extends far beyond the mechanical aptitude and demands high degree of versatility, since workers have to be frequently moved from one class of work to another to maintain balance in the factory; it also requires a thorough knowledge of mechanical engineering, particularly aircraft engineering, to enable the worker to fill in by himself the difference in specification between engineering drawing and operational drawings and instructions.

A factory with a large programme of production of civil aircraft will necessitate expansion of inspection, research and development organization. Some research facilities exist at the Hindustan Aircraft Ltd. and at the Indian Institute of Science, Bangalore, where a separate department was founded in '43. The equipment consists of wind tunnel and apparatus for radiological and microphotographic examination of castings.

AVERAGE ANNUAL IMPORTS OF AIRCRAFT AND AIRCRAFT PARTS

		Aircraft	Aircraft parts
In quinquennium ending :	No.	Val. in lakhs of Rs.	Val. in lakhs of Rs.
'33-34	21	2.17	2.82
'38-39	33	9.99	9.42
'43-44	13	4.83	59.54
'44-45	2	0.85	11.19
'45-46	1	0.02	19.25

There was a peak import of aircraft parts worth Rs. 2.45 crores in '41-42, this great increase being due to diversion of parts worth Rs. 1.67 crores from Burma.

LEASE-LEND EXPORTS TO INDIA AND DEPENDENCIES FROM THE U. S. A. IN 1944*

	No.	Million $
Bombers	541	124
Fighters	850	68
Transports	365	39
Communication aircraft ..	162	1
Trainers	383	9
Gliders	630	12
Aircraft parts (accessories not elsewhere specified)	..	24

**For. Comm. & Navig. U. S.*, 1944.

ALCOHOL

The term 'alcohol' was first applied to the spirits of wine, ethyl alcohol, and now it refers to a series of substances with similar characteristics. Ethyl alcohol is the active constituent of all intoxicating liquors obtained by the fermentation of saccharine materials. It is present in the form of esters in several volatile oils. It is now-a-days prepared in immense quantities, chiefly by fermentation, and finds numerous industrial uses, and is also being used as a motor fuel.

Pure ethyl alcohol, C_2H_6O, also known as 'absolute alcohol', is a colourless mobile inflammable liquid with a spirituous odour and a sharp taste (sp. gr. at 15.6°/15.6°, 0.7935, and 0.7851 at 25°/4°; wt. per gal., 6.60 lb./20° ; b. p., 78.4°; and freezing point, −114.4°). It is hygroscopic and is miscible with water in all proportions. Considerable heat is evolved when water is added to alcohol, the volume of the mixture showing a slight contraction. Alcohol is also freely miscible with most organic liquids, and is an excellent solvent. Its flash point is 18.3° (65°F.), and it burns with a pale blue flame. Its vapours form explosive mixtures with air.

Aqueous alcohol cannot be completely dehydrated by fractional distillation owing to the formation of a constant boiling mixture of b. p., 78.15° (alcohol, 95.6 ; and water, 4.4 per cent. by wt.). This mixture represents the highest concentration of alcohol possible under the usual methods of rectification.

Chemically, alcohol is a neutral substance. When conc. sulphuric acid is gradually added to alcohol, ethyl hydrogen sulphate is formed with the evolution of considerable heat. Ethyl hydrogen sulphate decomposes at 170° and gives ethylene. At temperatures below 145°, it reacts with a further quantity of alcohol and yields ether. The esters of alcohol are generally neutral, pleasant-smelling liquids, insoluble in water. Alcohol is attacked by several oxidizing agents and is converted successively into acetaldehyde and acetic acid.

Alcohol has a depressant effect on the central nervous system, and not a stimulating effect as was formerly supposed. The apparent exhaltation is due to its anaesthetic and hypnotic properties, owing to its inhibitory action on higher nerve centres. A strong dose of alcohol introduced into the stomach increases heart beat and causes a rise in blood pressure. Hence the use of brandy as a restorative.

Small quantities of dil. alcohol taken before food increase the flow of gastric juice and aid digestion. Alcohol has also a high food value as it is rapidly absorbed, and oxidised in the tissues ; 100 g. are equivalent to about 78 g. of fat. The continued use of strong alcohol, however, produces serious disorders in the stomach resulting in gastritis and other complications.

The normal concentration of alcohol in human blood is 0.004 per cent. When imbibed, its concentration in blood usually reaches a maximum in an hour and a half, and becomes normal again after 12-15 hrs. Symptoms of intoxication begin to appear when concentration reaches 0.15 per cent. Habitual drinkers show a higher tolerance.

Partially diluted alcohol (50-75 per cent.) acts as an antiseptic and is used as a sterilising agent in surgery. The maximum bactericidal effect is exhibited in concentrations of 70 per cent.

The use of alcohol as an exhilarating and intoxicating beverage is common throughout the world. *Toddy*, the fermented juice, obtained from several palms, has long been used by the poorer classes in India, and the distillation of spirit, *arrack*, from fermented rice, *toddy*, etc., has been known, since early times. Since the advent of the English into India, modern distilleries and breweries have been established in almost all the Provinces and important States. The potable spirits made are country spirit (*arrack* and spiced liquors), and liquors resembling imported spirit (rum, gin, whisky, and brandy). For alcoholic beverages, *vide* Breweries and Malt liquors, Distilleries and distilled liquors, Toddy and other indigenous fermented liquors, and Wines. This article is confined to the Industrial uses of alcohol.

Alcohol possesses excellent solvent properties, and it is used for the extraction of several drugs, and for the manufacture of tinctures and other medicinal preparations. It is also employed for the extraction of essential oils, and for the preparation of perfumes, essences and flavours. Alcohol dissolves shellac, rosin, and cellulose esters, and is widely employed as a solvent in the preparation of lacquers, varnishes and enamels. It is used as a process material in the preparation of numerous organic compounds, including synthetic drugs and dye-stuffs, especially for crystallization and purification.

Alcohol is used directly in the manufacture of several compounds such as ether, ethyl acetate, and other esters, acetic acid (vinegar), acetone, chloral, chloroform and iodoform. It is required for the manufacture of mercury fulminate which is largely used in detonators for explosives. It is a solvent in preparing T.N.T. Alcohol is also employed in the preparation of transparent soaps.

Alcohol (methylated spirit) is also widely employed as a heating agent. Solidified spirit used in cookers is prepared by dissolving stearic acid in alcohol and saponifying it with sodium hydroxide. On cooling, the soap (5-7 per cent.) forms a soft bulky solid occluding the spirit.

One of the most important developments in recent years is the use of alcohol as motor fuel. For this purpose, petrol is generally blended with up to 20 per cent. of absolute alcohol. Power alcohol has become prominent in most sugar-producing countries which depend upon imports for petrol.

Another recent development is the use of alcohol for the production of butadiene for the manufacture of synthetic rubber. The U.S.A. consumed 622 million gals. of alcohol from Jan. '42 to June, '45 for the production of synthetic rubber (*Industr. Engng. Chem.*, 1947, **39**, 934).

The minor uses of alcohol are in the preparation of certain adhesives, anti-freeze mixtures, brake-fluids, cutting oils, air foam solutions, dope thinners and de-icing agents. Alcohol is also used as preservative for anatomical specimens and as a dehydrating agent in microscopic technique.

The tax on alcoholic beverages and products forms an important source of revenue in several countries including India, and the duty levied depends upon the amount of alcohol present in the liquid. An accurate determination of the percentage of alcohol in dutiable products is of the utmost importance. This proportion, in England, is measured in terms of proof spirit defined by an Act of Parliament in 1816, as that which at 50°F. weighs exactly twelve-thirteenths of an equal volume of distilled water at the same temperature. This mixture has a sp. gr. of 0.91976 at 15.6°/15.6° and contains 49.28 per cent. by wt., and 57.10 per cent. by vol. of anhydrous alcohol. Spirits which contain a higher proportion of alcohol are said to be 'over-proof' and those which contain a smaller proportion, 'under-proof'. Over-proof strengths refer to the volume of proof spirit which would be obtained by diluting 100 vols. of the spirit with water, and under-proof strengths give the volume of proof spirit contained in 100 vols. of the spirit. Thus 100 vols. of 50° o. p. spirit on dilution with water will give 150 vols. of proof spirit; and 100 vols. of 50° under-proof spirit contain 50 vols. of proof spirit. The British standard is also adopted in India. American proof spirit is defined as containing 50 per cent. of its vol. of alcohol at 15.6° (42.52 per cent. by wt.). In the scale adopted for excise purposes 0 represents water, 100 proof spirit, and 200 alcohol. Standards by wt. and by vol. are also in vogue in other countries.

The determination of alcoholic strength of a spirituous liquid is known as alcoholometry, and is carried out by finding out the exact density of aqueous alcohol distilled from it. Its proof strength is obtained from accurately prepared 'spirit tables,'—giving sp. gr. at 60°/60° F. and at 80°/80° F. and the corresponding percentage of alcohol by wt., and by vol. and percentage of fiscal proof spirit. Correction tables for ascertaining real alcoholic strength from densities determined at temperatures 61-100° have been issued by the Central Bd. of Revenue in India.

When determining the alcoholic strength of spirituous liquors containing volatile acids, ammonia, essential oils, and other volatile constituents, acids and ammonia are fixed by neutralization before distillation. The removal of the volatile organic constituents often presents complicated problems. In the usual method for separating these, the distillate is saturated with common salt and is extracted with light petroleum (b. p., 40-60°). The saline alcoholic layer is separated and again distilled, and the density of the distillate determined.

The proof strength of rectified spirits may vary from 61° to 68° o. p. (91.8–95.8 per cent. by vol.) and the usual grade is 66° o.p. (92 per cent. by wt., or 95 per cent. by vol.). Ordinarily, alcohol carries with it some odour characteristic of the raw material from which it is prepared. In the perfumery industry, it is essential to use completely deodorised alcohol, and this is obtained by treating ordinary alcohol with activated charcoal and distilling it. B. P. alcohol (95 per cent.; sp. gr., 0.815-0.817) contains 94.7-95.2 per cent. by vol., or 92.0-92.7 per cent. by wt. of alcohol. It should be free from methyl alcohol and should comply with limit tests for acidity, alkalinity, oily or resinous substances, fusel

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oil and allied impurities, and aldehyde. This alcohol is diluted to concentrations varying from 90 to 20 per cent. of alcohol by vol. for various pharmaceutical purposes.

When 95 per cent. alcohol is refluxed with excess of quicklime for some hours and is distilled over, the concentration is raised to nearly 99.8 per cent. The last traces of water are eliminated by treatment with calcium or magnesium turnings to yield nearly chemically pure alcohol. B. P. dehydrated alcohol (absolute alcohol) contains not less than 99.4 per cent. by vol., or 99 per cent. by wt. of alcohol. When intended for injections, it should be filled into sterile containers under aseptic conditions. Anhydrous alcohol does not produce cloudiness when mixed with benzene, nor any pink coloration when shaken with a crystal of potassium permanganate.

Alcohol for industrial purposes is denatured, rendered non-potable by the addition of substances with objectionable odour and taste. The usual denaturants are wood naptha (methyl acetone), methyl alcohol, and mineral naptha (petroleum oils). These are added generally in the proportion of about 5 per cent. by volume. In addition, a small percentage of pyridine is also mixed to intensify the offensive odour. In India, denatured alocohol or methylated spirit is prepared from spirit of not less than 50° o. p. (80 per cent. by wt. of alcohol), by the addition of 0.5 per cent. of light caoutchoucine and 0.5 per cent. of crude pyridine bases. Light caoutchoucine is obtained on redistilling the liquid obtained by the slow dry distillation of waste vulcanised rubber. Methylated spirit is mostly used as fuel and for varnishes.

In the U. P. ‘ fuel alcohol ’ *i.e.*, rectified spirit used formerly as motor fuel, was denatured by the addition of 1 per cent. by vol. of kerosene, and power alcohol (99.5 per cent. of ethyl alcohol by vol.) is denatured by the addition of 2 per cent. of kerosene.

Specially denatured alcohol is supplied to industries where the presence of the usual denaturants is objectionable. Specific formulae, at least 57 in the U. S. A., and 47 in England, have been developed to meet the needs of various manufacturing industries. In the U. P., alcohol for the manufacture of transparent soap is denatured by the addition of 5 per cent. wood naptha, or caustic soda and castor oil (Dep. Industr. and Comm., U. P. Comm. Directory, '41-42, 17).

There is an absence of uniformity in the rates of excise duty levied on alcoholic beverages, and alcohol used for medicinal and other preparations, in the different Provinces and States. The duty on alcohol used for medicinal preparations is usually Rs. 5 per proof gal., and on alcohol used for toilet preparations and other non-medicinal purposes, Rs. 17-8 per proof gal. The duty on rectified spirit varies from Rs. 21 in Mysore, to Rs. 25-10 per proof gal. in Bombay and Sind. In most countries, rectified spirit issued to research institutes and educational institutions is exempt from tax. But this concession is not general throughout India.

MANUFACTURE

Alcohol is obtained by the fermentation of any saccharine or starchy material (C. P., 1046 ; *Kew Bull.*, **1925,** 193). The enzyme zymase present in yeast acts directly upon simple sugars and converts them into alcohol and carbon dioxide :

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Alcohol is also obtained from starches and even cellulose. These are first converted into simple sugars to enable zymase to act upon them. In the case of starchy materials, the degradation is generally brought about by the action of the enzyme diastase, present in germinating grains, chiefly barley. The saccharification of wood cellulose is brought about by digestion with acids.

Molasses, the syrupy mother liquor, left after the recovery of sucrose from sugarcane juice or beet root extract, forms the most important raw material for large scale manufacture of alcohol. Before the growth of the Indian sugar industry, Indian distilleries made use of *gur* or *jaggery*, molasses imported from Java, and *mahua* flowers (*Madhuca indica*), where available. Now indigenous molasses forms the chief raw material of the industry.

Molasses shows considerable variation according to source. Molasses for distilleries in the U. P. is marketed in two grades: the standard grade of 80° Brix or over, with 44 per cent. or above of fermentable sugars; and the ordinary grade containing 37-44 per cent. of sugars. The insoluble material in both is specified as under 5 per cent. In the U. S. A. cane molasses, also known as blackstrap molasses, is mostly imported from Cuba.

COMPOSITION OF MOLASSES*

	Water	Sucrose	Invert sugar	Ash	Other organic non-sugars.
Cane molasses	20	30	32	6	12
Beet molasses	20	50	trace	10	20

*Riegel, 339.

Owing to the large number of small sugar factories scattered in sugar cane growing areas, the supply of molasses to centrally situated distilleries has sometimes been difficult. Solidification of molasses by concentration has been attempted, but under Indian conditions, so far, it has not been found economical (*Biochem. Res. India*, 1944, **14**, 95). In recent years, American distillers have been using high test molasses, *i.e.*, molasses in a concentrated form. One gal. of high test molasses is equal to about 1.4 gal. of blackstrap molasses.

It is estimated that at present about 400,000 tons of molasses, calculated on the basis of a yield of 30 per cent. on the wt. of sugar manufactured, are produced annually in India as by-product of the sugar industry. According to the post-war development plans, the target for sugar production has been placed at 1.6 million tons per annum which will yield about 480,000 tons of molasses. Of this quantity, about 50,000 tons will be diverted to minor uses, such as, tobacco curing, and the balance, 430,000 tons will be available for production of alcohol. On the basis of a yield of 60 gals. of absolute alcohol per ton of molasses, it would be possible to manufacture 26 million gals. of alcohol annually (Rep. Panel on Sugar, Alcohol and Food-Yeast Industr., 1946, 17).

The *mahua* tree is found mostly in C. I. and in the C. P. It bears large clusters of cream coloured flowers (Feb.-Apr.). The ripe flowers which fall from the tree (end of Apr.), are collected (the yield per tree ranging from 2-4 md.). These are dried in the sun and sent to distilleries. On an average they contain 57 per cent. of fermentable sugars (invert sugar, 42.5-55 per cent.; and cane sugar, 2-15 per cent.) and yield 2.4 gal. of proof spirit per md. Chatterjee (*J. sci. industr. Res.*, 1944, **3**, 265) estimates that annually 50,000 tons of flowers may be collected which form a potential source of about 3.25 million gals. of alcohol.

Starch bearing materials, potatoes, rice, wheat, maize, etc., form another important source of alcohol (*vide Industr. Engng. Chem.*, 1939, **31**, 162). Potatoes were extensively used for the manufacture of alcohol in Germany, before the War ('39-45). Alcohol produced from grains costs more than that produced from molasses, and grains are chiefly used for the production of potable liquors. During the War, owing to shortage of molasses in the U. S. A., immense quantities of alcohol were produced (700 million gals. from late '42 to July '45) from wheat and wheat products, to meet military demands, and especially for the manufacture of synthetic rubber.

PRODUCTION OF INDUSTRIAL ALCOHOL
(190° PROOF IN THE U. S. A.)

	(Millions of Imp. gals.)	Per cent. of production from		
		Molasses	Synthesis (from ethylene)	Fermentation of grains and other carbon hydrates
'36-41 (annual av.)	102	72	20	8
'45	481	17	10	73

Owing to the present acute shortage of food-stuffs in India, grains cannot be diverted to the manufacture of industrial alcohol, and only small quantities may be allotted for the production of beer and potable spirit.

The waste liquors obtained during the manufacture of wood pulp by the sulphite process contain 2-4 per cent. of sugars, of which about 2/3 are fermentable. These liquors, when available in large quantities, are utilized for the production of alcohol in northern Europe and in N. America, but the spirit obtained is not always of high purity. Wood is another important raw material for the production of alcohol. Saccharification of cellulose is effected by treating it with dil. acid under pressure, and the sugars obtained are subsequently fermented with yeast. The yield of alcohol (95 per cent.) is about 21 gals. per ton of wood (Thorpe, I, 179).

The production of synthetic alcohol from ethylene has made considerable progress in Germany and the U.S.A. In Germany ethylene is derived from coke-oven gases, and in the U.S.A., by the cracking of petroleum hydrocarbons. The gas is absorbed in strong sulphuric acid under pressure (250-500 lb./sq. inch), and converted into ethyl hydrogen sulphate. When the resulting liquor is diluted with an equal vol. of water, the sulphate is hydrolysed, and the alcohol formed is separated by distillation, some ethyl ether being obtained as by-product (*Chem. Engng. News*, 1947, **25**, 1792). The process requires large quantities of acid-resisting equipment, and the initial outlay on plant is comparatively high.

FERMENTATION AND RECTIFICATION

For fermentation, molasses is diluted with water to produce a solution or 'mash' containing about 10 per cent. sugars. To this some ammonium sulphate (0.015 lb. per 2.5 gals. of molasses) is added to supply nitrogen for growing yeast and also some sulphuric acid (0.17 lb. of 60° Be'. per 2 gals. of molasses), to produce slight acidity (pH, 4.9-5.0) which hinders the growth of unwanted bacteria. The 'mash' thus prepared is charged into large wooden vats or steel tanks, and fermentation started by the addition of yeast (*ca.* 15 % by vol. of active wash).

In larger distilleries, yeast for fermentation is cultivated from selected strains. The isolation of strains of yeast active in concentrations of 10-12 per cent. of alcohol has been claimed. For the selection of yeast, agar-agar is inoculated with specimens of yeast, and after a day or two, each culture is transferred to a separate flask containing a dil. solution of *gur*. The sample giving the max. conversion of sugar into alcohol is propagated in a dil. solution of molasses, and allowed to develop in another tank of 2,000 gal. capacity, containing molasses (*d*, 1.055-1.060). After 8-12 hrs. when density falls to 1.025, the active wash is added to the fermentation tanks (6-10 per cent. by vol. of each tank).

Owing to heat evolved during fermentation, the temperature in the vats rises gradually, and is controlled by means of cooling coils, or cold water spray. Fermentation starts within a few hours after the addition of yeast, becomes very vigorous after 24 hrs. and is usually complete in 48-72 hrs., when the sp. gr. of the mash becomes stationary. At this stage it contains 6-8 per cent. of alcohol. On an average 0.4 gal. alcohol is obtained from 1 gal. of molasses. Strict technical control is essential to ensure satisfactory yield.

Yeast furnishes two enzymes: invertase, which hydrolyses cane sugar to glucose and fructose :

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 \text{ (glucose)} + C_6H_{12}O_6 \text{ (fructose)}$$

and zymase which brings about alcoholic fermentation of the two latter. The conversion of carbohydrates into alcohol is about 90 per cent. During fermentation, small quantities of higher alcohols (fusel oil), organic acids and glycerine are also formed as by-products.

Alcohol is separated from the fermented mash by distillation. Most of the smaller distilleries, especially those producing potable liquors, employ pot-stills while the larger distilleries make use of patent-stills, such as Coffey's still or Ilge's or Barbet's still. Coffey's still consists of two columns, the analyser and the rectifier. The fermented mash enters the analyser at the top and follows a zig-zag course down the column. Steam introduced at the bottom and travelling counter-current to the mash deprives it of its alcohol content, and the exhausted mash, 'slop,' is run out. The vapours (steam and alcohol) issuing from the top of the analyser enter the rectifier at the bottom.

The rectifier consists of a specially designed fractionating column with a number of chambers. During the upward passage of vapours, the less volatile constituents, steam and fusel oil ('feints'), gradually condense, and are drawn off from the base of the column. Pure alcohol is drawn from a higher part of the still where the temperature is roughly equal to its boiling point. The head-products, which are very small, consist of aldehydes, formic esters, etc., and owing to their greater volatility pass out through the top of the column along with a small quantity of uncondensed alcohol. This fraction is being used in the manufacture of methylated spirit. The feints consist of a mixture of alcohol and fusel oil and are recycled for the recovery of alcohol; fusel oil is removed from the receiver every two or three days.

The Barbet still is said to be more economical in steam consumption. Several new stills, of similar design, made in India, have come into operation during the last War.

The highest concentration of alcohol that can be obtained by fractional distillation is the constant boiling mixture containing alcohol, 95.6 ; and water, 4.4 per cent. by wt. Unless special care is exercised, alcohol obtained from patent-stills contains only 90-95 per cent. by vol. of alcohol (85.6-92.4 per cent. by wt.), and this is known as rectified spirit.

Further dehydration of 95 per cent. alcohol was formerly carried out by refluxing it with quicklime, followed by distillation. But this process is uneconomical for large-scale production. In '23, the Usines de Melle developed a plant for the commercial production of absolute alcohol, based on an observation of Young, that benzene, when added to 95 per cent. alcohol and distilled, gives rise to a ternary azeotropic mixture boiling at 64.9°. Since then, absolute alcohol has been manufactured in very large quantities for use as solvent and as motor fuel.

In azeotropic distillation the ternary mixture (alcohol + benzene + water) passes over first, leaving behind alcohol. The excess of benzene forms a binary azeotropic mixture with alcohol of b.p., 68.2°. This distils over next leaving behind absolute alcohol.

Other recent methods make use of dehydrating agents, such as, anhydrous alkali acetates and gypsum (*vide Int. Sugar J.*, 1933, **35**, 266 and 346), or counter-current extraction with liquids of higher boiling point, such as, glycerine and glycol.

In azeotropic distillation the third component added is called an entrainer. Other organic liquids, such as, ethyl acetate, toluene, hexane, carbon tetrachloride, and trichloroethylene also may be used as entrainers. The Drawinol process employed in Germany for the production of absolute alcohol uses dichloroethylene as entrainer (*Int. Sugar J., loc. cit.*, 29 and 71). Othmer and Wentworth (*Industr. Engng. Chem.*, 1940, **32**, 1588) have observed that diethyl ether also acts as an entrainer forming a binary azeotropic mixture with water, and developed a plant for the dehydration of alcohol under pressure (100 lb.).

Benzene, however, is the most widely used entrainer. The result of azeotropic distillation may be expressed thus (parts by wt.):

[alcohol, 95.5+water, 4.5]+benzene, 45=
[alcohol, 11.2+water, 4.5+benzene, 45]
+absolute alcohol, 84.3.

Complete dehydration is effected by using a slight excess of benzene.

The ternary mixture separates into two layers,: the upper layer consisting mostly of benzene and alcohol and the lower layer, of dil. alcohol and benzene.

	(Per cent. by wt.)		
	Alcohol	Water	Benzene
Total distillate ..	18.5	7.4	74.1
Upper layer (84 per cent. by vol.)	14.5	1.0	84.5
Lower layer (16 per cent. by vol.)	53.0	36.0	11.0

In industrial plants, for continuous dehydration of 90-95 per cent. alcohol (Melle's First Technique), the upper layer of the ternary distillate is returned to the main distilling column, and the lower layer is fractionated in a second distilling column to recover benzene and concentrated alcohol, which are recycled.

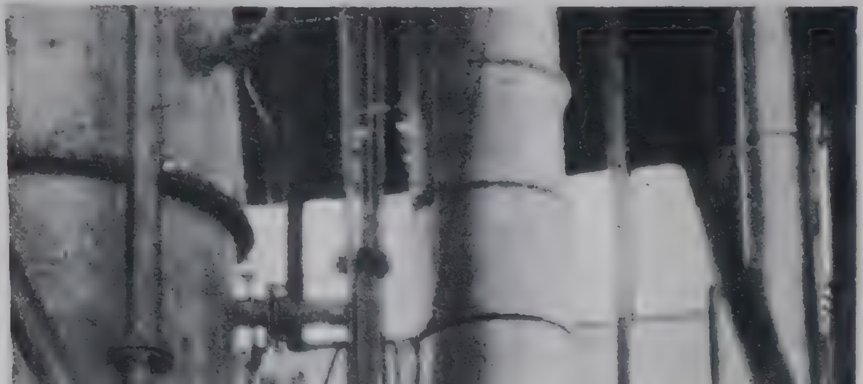
Benzin (hydrocarbons from petrol), b. p., 100-101°, is said to give an easier separation although it carries with it more of alcohol. On a technical scale the best results are obtained with a mixture of benzene and benzin. There is a slight loss of entrainer, which varies from 0.025 to about 0.2 per cent. of the amount of dehydrated alcohol produced. The traces of entrainer which may be left in the final product are removed by filtering it through activated charcoal.

The production of rectified spirit requires on an average 3000 lb. of steam per 100 gals. of alcohol. For subsequent rectification and dehydration to produce alcohol of 99.8 per cent. concentration, another 1500-1750 lb. of steam are necessery. The last traces of water are the most difficult to remove, and require an additional 250-500 lb. of steam per 100 gal.

A further development, based on the same principle, has been the production of absolute alcohol directly from the wash (Melle's Fourth Technique). The plant consists of three main distilling columns. The wash enters into the first where it is divested of its alcoholic content. The vapours pass into a second column where alcohol undergoes further concentration. Into this, the entraining liquid is introduced and alcohol of high strength (98.5-99 per cent.) mixed with a little of the entrainer passes on to a third column where dehydration is completed, and absolute alcohol is drawn off from the bottom of the third column. This process has the advantage of lower steam consumption, but it cannot be readily switched over to the production of rectified

1. FERMENTATION TANKS

2 RECTIFYING COLUMN



3 DEHYDRATING COLUMN

pirit as in the case of the First Technique Reilly, Distillation, 1936, 85).

The principal by-products in a distillery are carbon dioxide, and fusel oil.

Carbon dioxide liberated during fermentation is nearly equal in weight to the amount of alcohol formed and it is consequently an important by-product. In modern distilleries fermentation is carried out in closed vats, the gas formed being led out into compressors and filled into cylinders. Fusel oil is collected as hot feints. It is separated from ethyl alcohol by subsequent fractional distillation. It consists of a mixture of higher alochols, chiefly amyl, butyl and propyl alcohols, and is now a valuable raw material in the varnish industry. Fusel oil obtained is about 0.04 per cent. of the quantity of alcohol produced.

Among waste products of distilleries, the spent wash contains : K_2O, 6.0 ; P_2O_5, 0.03-0.05 ; N, 0.5-0.9 ; and organic matter, 40 g./l. The potash in it may be recovered by concentrating the liquor and burning the thick residue in a furnace. According to Iyengar (*Biochem. Res. India*, 1944, **14**, 94) slops from the Mandya Distillery of sp. gr., 1.032/26.5°, and acidity, 0.76 g./l., contain : potash, 0.59 ; phosphate, 0.11, nitrogen, 1.02 ; unfermented sugars, 0.05; ethyl alcohol, 0.004 per cent ; and give on evaporation 6.0 per cent. of residue. The Mandya Distillery produces 24,000 gals. of slop per day, corresponding to 2700 lb. of potash, 523 lb. of phosphate and 4617 lb. of nitrogen. He suggests that this may be used directly as manure if the soil is alkaline.

Modern methods of distillation appear to have been introduced into India only in the latter part of the last century. The first large distillery in northern India was erected by Messrs. Carew & Co., at Rosa near Shahjahanpur in the U. P. about the year 1835, to produce rum and other potable liquors. Coffey stills were installed in 1875 when the distillery commenced the production of rectified spirit. In southern India, Messrs. Parry & Co. started a distillery at Nellikuppam (South Arcot dist., Madras) in 1848 using pot-stills, and later equipped it with Coffey stills, and began the production of rectified spirit in 1904. In that year there were 8 registered distilleries in India (C. P., 1047), and subsequently a number of new distilleries came into existence in various parts of India. With the growth of the Indian sugar industry since 1932, the disposal of large quantities of molasses became an acute problem, and its conversion into power alcohol was suggested as one of the solutions (Rep. Jt. Power Alcohol and Molasses Inquiry Comm., Bihar and U. P., 1938 ; Rep. Power Alcohol Comm., Madras, 1939).

Before the Second World War, there were at least 25 large distilleries, capable of producing rectified spirit, with an estimated capacity of 9 million gals. per annum. By about '44, 8 new distilleries came into existence in the U. P. and, since then, 4 more (1 each in the U. P. and the Punjab, and 2 in Bihar) are reported to have begun production. The expansion in capacity during the War has been estimated at 7 million gals. per annum (Minist. Industry and Supply).

During the War, the demand for alcohol rose steeply owing to increased consumption by the Defence Dept. but after '45, production declined, and at present, it is estimated to be only 7 million gals. per annum. In '42-43 the total demand for Defence purposes, according to Thomas (Rep. Develop. Industr. War Supplies, 1944, 50), was 3.4 million gals., distributed thus : Ordnance Factories and Services, Railways, and Central Provision Office, 1 million gals. ; drugs and medicines, 0.3-0.5 million gals. ; the rest, for brake fluid, Air Forces, de-icing spirit, aeroplane dopes, fuel for Tommy cookers, etc.

In Indian distillery practice, molasses

of sp. gr., 1.40-1.47 is diluted with water to give a solution of *d*, 1.065-1.080, containing 12-13 per cent. of fermentable sugars. To this are added 0.25-0.35 per cent. of ammonium sulphate, and about 0.27 per cent. of sulphuric acid (*d*, 1.75), to raise the pH to 4-5. The molasses solution is then mixed with 7-10 per cent. of active wash (*d*, 1.025) in large steel tanks of 10,000 gals. capacity. The addition of active wash lowers the initial density to 1.040-1.045. The temperature at the commencement of fermentation is usually 30°, and towards the end, 33°. During fermentation it is not allowed to rise above 36°. The fermentation is usually complete in $1\frac{1}{2}$-3 days depending upon the season and the density falls to about 1.025-1.028. The alcohol content at this stage varies from 5-7 per cent.

Coffey stills ordinarily yield rectified spirit of 92-94 per cent. conc. by vol. (60-65° o. p.). Barbet stills are more efficient and the conc. of alcohol produced is 96 per cent. by vol. (69.3° o. p.).

The yield of rectified spirit varies from 54-56 gals. per ton of molasses representing a conversion of 90-95 per cent. Usually for the manufacture of 100 gals. of rectified spirit, the materials required are : molasses, 50-55 mds. ; sulphuric acid (*d*, 1.75), 5.5-6.4 lb. ; ammonium sulphate, 5.3-7.0 lb. ; and steam, 50-55 lb. In summer a slightly smaller percentage of ammonium sulphate (about 25 per cent. less), and a somewhat higher percentage of acid (about 20 per cent. more) are required.

INDIAN DISTILLERIES CAPABLE OF PRODUCING RECTIFIED SPIRIT IN 1944*

Province or State	No. of distilleries	Capacity in 1,000 gals. per annum
Bihar	1	289
Bombay	2	1,419
Bengal	4	1,335
Madras	2	65
Punjab	3	62
U. P.	15	7,89
C. P.	1	28
Mysore	1	54
Hyderabad	1	72
Rampur	1	54
Travancore	1	24
Baroda	1	24
Total ..	33	14,78

* Ex Rep. Panel Sugar Alcohol & Food-Yeast Industr., 194
loc. cit., Appx., 27.

PRODUCTION OF ALCOHOL IN INDIA *

(1000 proof gals.)

	Potable spirit	Rectified spirit	Denatured spirit	Total
'36—37	5,682	410	2,320	8,41
'37—38	6,692	420	2,223	9,3
'38—39	6,788	487	2,169	9,44
'39—40	6,267	558	2,421	9,24
'40—41	7,164	811	2,612	10,5
'41—42	7,958	1,311	2,587	11,8
'42—43	10,148	1,273	2,172	13,5
'43—44	12,848	1,624	2,177	16,6
'44—45	12,848	2,201	2 604	17,6

* *Mon. Statist. Production sel. Industr. India.*

PROVINCIAL EXCISE REVENUE RECEIPTS FROM COMMERCIAL SPIRITS INCLUDING DENATURED SPIRIT AND MEDICATED WINES
(In lakhs of Rs.)

	'38-39*	'44-45**
Bengal	2.32	47.43
Bihar	0.46	5.53
Bombay	3.46	3.22
Central Govt.	0.08	3.50
Punjab	1.06	0.98
U. P.	0.35	1.55
Others	1.49	1.41
Total ..	9.22	63.62

* *Statist. Abstr. Br. India.* '30-31 / '39-40, 358.
** Ex Provincial budgets.

AVERAGE ANNUAL IMPORTS OF SPIRITS (OTHER THAN POTABLE SPIRIT) INTO BRITISH INDIA
(Qty. in 1000 gal. and val. in lakhs of Rs.)

Quinquennium ending	Potable spirit (brandy, gin, rum, whisky and liquors)		Spirit present in drugs		Spirit perfumed		Denatured spirit		Other sorts	
	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.
'33-34	809	109.0	119	35.3	9	7.4	880	9.3	32	8.4
'38-39	538	82.9	130	37.3	7	6.8	354	3.5	24	8.1
'43-44	483	125.8	99	30.9	3	4.1	227	2.5	19	7.0
In '44-45	388	75.3	99	38.7	0.08	0.2	..	..	16	9.4
„ '45-46	584	124.4	132	50.6	3	2.3	..	..	39	20.0

In '38-39, the revenue from imports of potable spirit was Rs. 132 lakhs, and from other forms of spirit, Rs. 16.2 lakhs; and in '43-44, Rs. 158 lakhs, and Rs. 7.5 lakhs, respectively.

The customs duty on most forms of potable spirit is, at present (1947), Rs. 56-4 per gal. of proof spirit; on spirit present in drugs and medicines, where strength is not to be tested, Rs. 48/- per gal., otherwise, Rs. 34-13; on perfumed spirit, Rs. 60 per gal., or 25 per cent. *ad valorem*, whichever is higher, *plus* one-half of total duty; and on denatured spirit, 114 per cent. *ad valorem.* The preferential rate for spirit in drugs and medicines from the U. K. is lower by 10 per cent.

POWER ALCOHOL

Since the commencement of industrial production of absolute alcohol, it is being extensively used in admixture with petrol as motor fuel in several countries, such as, France, Germany, Austria, Sweden, and Brazil. Alcohol blends, containing not more than 25 per cent. of alcohol by vol., may be used interchangeably with neat petrol of equal anti-knock rating. Such blends usually contain 5-25 per cent. of alcohol. These differ from petrol in their physical and chemical properties to the same degree as various commercial petrols. Only the latent heat of vaporization increases rapidly, with increase in the proportion of alcohol. The characteristic properties, of alcohol, *i. e.*, its higher latent heat of evaporation, and lower cal. val., do not become prominent until its proportion rises above 25 per cent. (Hubendick, ex Rep. Jt. Power Alcohol & Molasses Inquiry Comm. Bihar and U. P., *loc. lit.*, 42).

PHYSICAL AND CHEMICAL PROPERTIES OF ALCOHOL BLENDS*

C_2H_5OH content, c.c./100 c.c. of blend	Sp. gr. (25°/4°)	Fluidity (25°)	Water-holding capacity (c.c./100 c.c.) 0°	20°	Latent heat of evaporation at atm. cal./c. c.	Cal. val., lower, including latent heat constant vol. cal./c.c.	Air-fuel ratio for complete combustion by wt.
0	0.7212	215.3	0	0	54.5	7700	14.8
4	0.7225	217.6	0.080	0.104	58.5	7600	14.6
10	0.7257	207.6	0.245	0.347	64.8	7470	14.2
15	0.7292	200.6	0.417	0.589	70.5	7450	13.9
20	0.7323	191.6	0.589	0.832	75.8	7240	13.6
30	0.7384	175.1	0.938	1.357	86.4	7000	13.1
100	0.7859	97.1	..	..	170.2	5380	9.1

* Christensen, *Industr. Engng. Chem.*, 1936, **28**, 1089.

The substitution of alcohol blends in a motor engine, without change in ignition or carburettor adjustments, does not result in any decrease in power output, or increase in specific fuel consumption. Instead, there may be a gain in power output and lowering in specific fuel consumption, and this will be the case particularly when the engine is operated at part throttle and with air-fuel ratios lower than those for maximum economy (Christensen, *loc. cit.*). With the carburettor and spark set for the mean of the optimum values, for the two types of fuels, little difference in power, acceleration, or fuel consumption, is observed with a 10 per cent. blend or even with a 20 per cent. blend under many operating conditions (Bridgeman, *Industr. Engng. Chem.*, 1936, **28,** 1102).

Ethyl alcohol has an octane number of about 90, and in blends it serves the purpose of increasing the fuel characteristics of motor spirit. It raises the octane rating of petrol of 60-70 octane number by approximately 0.9 unit per vol. per cent. of alcohol added, within the limits of 5-20 per cent of alcohol. 10 per cent. and 20 per cent. of alcohol by vol. are equivalent to about 1 and 2 c. c. of tetraethyl lead per gal. of petrol. However, the anti-knock effect of both alcohol and ethyl lead depend upon the petrol used.

Owing to better anti-knock characteristics, alcohol can be used in engines with higher compression ratios. The fuel consumption for a 20 per cent. blend at 6.8 : 1 compression ratio is identical with that for petrol at 5.0 : 1 compression ratio, showing that an increase in compression ratio of 36 per cent. is required in the case of the blend to compensate for the lower heating value of the alcohol in the blend (Lichty and Phelps, *Industr. Engng. Chem.*, 1938, **30,** 222).

Road tests for comparing fuel consumption are extremely difficult to standardise. Hence, numerous varying results are reported (Egloff and Morrell, *Industr. Engng. Chem.*, 1936, **28,** 1080 ; Christensen, *loc. cit.*). In general, the mean values show a gain in mileage with the blend (10 per cent.) amounting to 5 per cent. at 20 miles per hr., falling to 1 per cent. at speeds of 40 miles per hr. The average fuel economy with petrol in a particular test was 15.9 miles per gal., and for a 10 per cent. blend, 15.85 miles per gal. In another test at a speed of 40 miles per hr., fuel economy for petrol was 16.54 miles per gal., and with the blend 16.02 miles per gal.

In road tests carried out by Mr. J. Charlton (ex Rep. Jt. Power Alcohol and Molasses Inquiry Comm., Bihar and U. P., *loc. cit.*, 67) the carburettor of a 20.9 h. p. car was previously adjusted for economy and was not altered in any way during the tests. Alcohol-petrol blends gave a slightly higher mileage per gal. than neat petrol :

	Miles per gal.
1. Burma Oil Company petrol	21.13
2. 15 : 85 mixture..	22.50
3. 25 : 75 ,, ...	22.73

One of the principal difficulties in the use of alcohol-petrol blends is the tendency of blends to absorb water from the sweating of tanks, or from other causes, and the consequent separation of alcohol from blends, especially at low temperatures. To overcome this difficulty, the use of blending agents, such as, benzene or toluene, and higher alcohols, is suggested. The higher alcohols are approximately 10 times more effective than aromatic hydro-carbons in raising the water tolerance. This defect, however, is not a serious disadvantage in India where atmospheric temperature is generally well above 0°.

WATER TOLERANCES OF BLENDS OF ETHYL ALCOHOL AND AN AVERAGE COMMERCIAL PETROL*

Temp. °F.	Water tolerance, vol. per cent. 5 per cent. blend	10 per cent. blend	20 per cent. blend
104 ..	0.19	0.46	1.11
68 ..	0.15	0.35	0.83
32 ..	0.11	0.25	0.59
—4 ..	0.07	0.18	0.40
—40 ..	0.05	0.11	0.26

* Bridgeman, *loc. cit.*

Vapour lock, interference with fuel feed system as a result of formations of vapour or gas, is caused by the use of a fuel which is so volatile that boiling occurs in the fuel feed lines, the capacity of which for handling vapour is limited. The increase in vapour pressure (Reid) in 20 per cent. blend is approx. 0.5 lb./sq. in., and 0.8 lb./sq. in. in a 10 per cent. blend. Accordingly there is little difference between the vapour locking characteristic of petrol, and of the same petrol blended with 20 per cent. of alcohol. Starting will be easier above 0°F. with 10 per cent. blend, than with petrol (Bridgeman, *loc. cit.*). With 20 per cent. blend there is no difficulty in starting even at the minimum temperature encountered in India.

Wawrziniok showed that with metals, excepting tin, less corrosion is produced by alcohol than by petrol. In the distribution of 20 per cent. alcohol blends in Sweden, during a considerable period no abnormal corrosion of any kind was observed by Hubendick. However, both ethyl and methyl alcohol react with magnesium and aluminium at high temperatures, and it is possible that corrosion of these materials occurs within the combustion chambers if fuels of high alcohol content are used, and if the fuel enters the cylinders in the liquid state. Corrosion due to acetic acid formation also might occur with fuels of very high alcohol content (Christensen, *loc. cit.*).

Blends containing not more than about 25 per cent. of alcohol by volume are in no way different from petrol as regards lubrication.

When using fuel alcohol in petrol run motors, certain modifications to the carburettor and air supply are necessary owing to differences in the properties of the two fuels (Verman and Nair, *J. sci. industr. Res.*, 1946, **4**, 601).

PROPERTIES OF PETROL AND RECTIFIED SPIRIT

Properties	Rectified spirit (95 per cent. by vol.)	Petrol
Sp. gr. at 60°F.	0.816	0.739
Viscosity in centipoises at 30°	1.175	0.402
Total heat for complete evaporation at 760 mm. from 0°. Cal./g.	255 (for 100 per cent. alcohol)	138
V. p. in mm. of Hg. at 30°	77	145-185
V. p. in mm. of Hg. at 10°	24	70-90
Net cal. val. (B. Th. U./gal.)	87,230	139,700
Theoretical quantity of air required for complete combustion in lb./lb.	8.4	14.3
Indicated thermal efficiency in per cent., at compression ratios of —		
5.0 : 1 ..	32.5	31.7
7.0 : 1 ..	38.2	37.4

The ratio of mileage per gal. of spirit to that of petrol is 64 per cent. and 63.8 per cent. respectively, for compression ratios of 5 : 1 and 7 : 1, the usual range in motor vehicle engines. The rate of flow of spirit to the engine has to be increased to 1.56 times that of petrol, by altering suitably the size of the carburettor jet. Further, on account of the higher sp. gr. of rectified spirit, the float will have to be weighted down to the correct level. Also, owing to the smaller quantity of air required for the complete combustion of alcohol, the amount of air entering the cylinders is to be regulated by modification of the air inlet, or by operating the choke.

Lichty and Ziurys (*Industr. Engng. Chem.*, 1936, **28,** 1094), in their study of engine performance with petrol and alcohol (190° U. S. proof), found that at max. power output (air-fuel ratios of 7 : 1 for alcohol and 12 : 1 for petrol) fuel consumption was about 60 per cent. by wt. or 50 per cent. by vol., higher with alcohol than with petrol, for the same output of power. Although higher compression ratios may be used with alcohol, the advantage is more than offset by the lower heating value of alcohol compared with petrol.

Verman and Nair (*loc. cit.*) conducted road tests with a 3 ton Chevrolet truck and a Ford Station Wagon. In the case of the truck they obtained a mileage ratio of 67.6 per cent., using a jet of twice the size of the petrol jet, and a mileage ratio of 65.7 per cent. by mere choke control without any change in the jet. With the Station Wagon, with spirit jet area 2.0 and 1.7 times the petrol jet area, the mileage ratios were respectively 60 per cent. and 59.3 per cent. (*vide* also *Sci. & Cult.*, 1945, **5,** 698 ; *J. Indian chem. Soc., Industr. & News Ed.*, 1943, **6,** 105). Performance on spirit was quite good on long runs, but not so satisfactory on short runs, involving frequent starts and stops. For satisfactory driving under all conditions through city traffic, the idling performance has to be improved. Finally when atmospheric temperature falls below 70°F., owing to the lower vapour pressure of alcohol, a special starting arrangement such as the heating of the carburettor and intake system, or providing alternate petrol supply will be necessary.

POWER ALCOHOL IN INDIA

The distillery of the Mysore Sugar Co. was the first to produce power alcohol in India using the Melle 1st technique. Since '39, this distillery has been producing on an average about 1.4 lakh gals. per annum, for blending with petrol (15 per cent. alcohol) used in the Mysore State. The Bodhan distillery of the Hyderabad Construction Co. started operating the 4th technique in '42, and has been producing annually 3 lakh gals. of power alcohol. The Central Distillery and Chemical Works of Meerut, also using the 1st technique, has been producing power alcohol since '42, and its production rose to 3 lakh gals. in '45-46 (*Indian Sugar*, 1947, **10,** iv, 75).

During the last War, eight large distilleries in the U. P. were equipped with power alcohol plants similar in design to that of the Meerut plant. They were, however, producing only fuel alcohol from Mar., 45 at the rate of about 2.5 lakh gals. per month (*Indian Sugar*, 1946, **9,** 512). Owing to acute shortage of petrol in the U.P., lorries of certain size were obliged to run only on fuel alcohol. They started production of power alcohol in '46-47. The combined capacity of these plants is about 5 million gals. per annum, and two more, each of a million gals. capacity, are in the course of construction. In the Bombay province one distillery is equipped with power alcohol plant.

In '46-47 the total production of fuel alcohol and power alcohol in India was 19.2 lakh gals. and the revenue from this, Rs. 14.8 lakhs. Hitherto, in spite of the much larger plant capacity, the production of power alcohol has not risen above 1 million gals. per annum. Molasses, which was formerly a waste product of no value, has risen considerably in price after the expansion of the alcohol industry, and for economic production of alcohol, proper control and distribution of molasses are essential.

The distribution of power alcohol presents certain difficulties in order to protect against its diversion for potable purposes. The denaturant must be non-corrosive and also should not form any resin inside the cylinders. The U. P. Government requires the addition of 2 vol. of kerosene to 100 vol. of power alcohol, and the Panel has suggested the use of 5 per cent. of petrols as denaturant (*vide* also Rep. Panel Sugar Alcohol Food-Yeast Industr., *loc. cit.*, Appx. 22, 46).

Sugar-cane cultivation and sugar industry are concentrated in the U. P. and Bihar. U. P. is the largest producer of alcohol in India, and will continue to have the lead even in the scheme of expansion proposed by the Panel on Sugar, Alcohol and Food-Yeast Industries. In '45-46 the production of different grades of alcohol in the U. P. in lakhs of gals. was : methylated spirit, 10.04 ; rectified spirit, 23.58 ; fuel alcohol, 17.13 ; and power alcohol, 3.06 (*Indian Sugar*, 1947, **10,** iv, 75).

PROPOSED DISTRIBUTION OF POWER ALCOHOL PRODUCTION IN INDIA (FIVE-YEAR TARGET)

Province	Production (lakhs of gals.)
U. P.	116.5
Bihar	45.0
Bengal	7.5
Bombay	12.5
Madras	8.0

The Panel has estimated that in large distilleries cost of production of power alcohol is about As. 8 per gal., when the price of molasses is As. 6 per md. This estimate, however, is subject to a number of variable factors. The controlled market price of rectified spirit in the U. P. during '45-47 was Rs. 1-8 per gal. and the ex distillery price of fuel alcohol, As. 14½. The sale price of fuel alcohol, including excise duty and distribution charges, was Rs. 2-1-6. To this has to be added As. 2-3 extra for transport charges. The U. P. Government fixed the price of power alcohol at As. 11 per gal., but the present cost of production according to the Central Distillery at Meerut is at least Rs. 1-1 per gal.

In general, the cost of production of alcohol is nowhere less than that of petrol, the landed cost of which at Indian ports is *ca.* As. 6½ per gal. It is expected that the 20 per cent. blend now in use in the U. P and recommended for general adoption in India will cost the consumer As. 1½-2 more per gal. than ordinary petrol.

The capital invested in the industry is now nearly a crore of rupees. New plants of one million gal. capacity are estimated to cost Rs. 10 lakhs each. Of this amount, only Rs. 2-3 lakhs are for imported equipment.

The pre-War annual consumption of petrol in undivided India was about 100 million gals., of which only 17 million gals. were produced in the country. The present rationed annual consumption in the Indian Union is 120 million gals., and production, 12 million gals. (*Capital*, 1948, **120,** 54). Thus 90 per cent. of Indian requirements of petrol have to be imported from the Persian Gulf area, Burma, and other sources. Consequently, when the maximum production of power alcohol is reached, India will effect a saving in her imports of petrol. In addition to utilizing the entire quantity of molasses produced, India will have a strategic industry supplying an alternative fuel, partially compensating for her present poverty in petroleum resources.

ALKALIS

The term 'alkali' is applied to a number of bases which neutralize acids. Alkalis are generally soluble in water, and the solutions are soapy to touch. Solutions of caustic alkalis, such as, sodium and potassium hydroxides are corrosive and dissolve wool and skin. Sodium and potassium carbonates effervesce with acids, and they are not corrosive. They are called mild alkalis.

The most important alkalis are sodium carbonate, sodium bicarbonate and sodium hydroxide, and their production is an important branch of the Chemical Industry. They are required in very large quantities for the manufacture of glass, paper, soap, textiles, etc., and in numerous other industries.

Sodium Carbonate

The decahydrate of sodium carbonate, $Na_2CO_3.10H_2O$, also known as washing soda, is obtained by crystallization of a solution of sodium carbonate at temperatures below 35°. It occurs as colourless, transparent, rhombic crystals, which effloresce when exposed to air, forming the monohydrate, $Na_2CO_3.H_2O$. The crystals of the decahydrate contain over 60 per cent. by wt. of water, and in tropical climates they melt and dissolve in their own water of crystallization. When heated, they begin to melt at about 50° and become anhydrous above 80°. The crystals dissolve in water with absorption of heat, and solutions of sodium carbonate have a strong alkaline taste and are alkaline to litmus.

Crystals of the monohydrate, $Na_2CO_3.H_2O$, also known as 'crystal soda,' are obtained when crystallization is carried out at temperatures above 35°. Unlike the decahydrate, these are not efflorescent, and dissolve more readily in water with evolution of heat.

Anhydrous sodium carbonate also known as soda ash is sold in two grades : 'light ash' and 'heavy ash'. The former weighs 35 lb. per c. ft. and the latter, 50-67 lb. per c. ft. Heavy ash costs less in packing and is preferred in the glass industry. The usual impurities in soda ash are small amounts of sodium chloride and sodium-sulphate, but the ash prepared by the Solvay process is above 99 per cent. pure.

Sodium carbonate is still marketed on the basis of its Na_2O content calculated from old atomic weights (New York and Liverpool test). Pure sodium carbonate contains 58.5 per cent. Na_2O; it is graded as 60.4 per cent. Na_2O. Other methods of grading are also prevalent on the Continent, but it would be more convenient to quote the actual percentage of Na_2CO_3.

With the exception of lime, soda ash is the cheapest article consumed in several manufacturing industries. Large quantities are used for the manufacture of caustic soda, sodium bicarbonate and other chemicals. Next, in order of consumption, comes the glass industry. Considerable quantities of sodium carbonate are also used in water softening, oil refining, metallurgy, laundering, and for washing purposes.

Sodium carbonate, both crystalline and anhydrous varieties, is used in the preparation of bath salts. A very dil. aqueous solution (0.5 per cent.) is employed to relieve irritation in eczema.

'Modified sodas' consist of mechanical mixtures of sodium carbonate and bicarbonate. These are used in cleaning operations where an alkali less strong than sodium carbonate is required. Where a strong alkali is necessary, as in water softening, metal cleaning, bottle-washing, etc., 'causticised ash' consisting of mixture of soda ash and caustic soda is employed.

Natural soda occurs in the form of deposits in many dry lake beds in various parts of the world, and in the dissolved state, in the brine of certain alkaline lakes. The deposits consist chiefly of the sesquicarbonate, $Na_2CO_3 . NaHCO_3 . 2H_2O$, known as *trona* or *urao*, together with small amounts of sodium sulphate, sodium chloride, etc. The largest of the deposits is in Lake Magadi (East Africa) and is estimated to contain 20 million tons. The other prominent natural occurrences are in (Owens Lake and Searles Lake), California, and in Manchuria and Inner Mongolia. For the occurrence of alkali carbonates in certain Indian soils and Lakes, *vide* Alkaline lakes and soils.

Before the manufacture of soda ash by chemical processes, it was obtained mostly from the ashes (*barilla*) of certain seaweeds, (*Salsola* spp.), occurring along the southern coasts of Spain and France, and from natural deposits, alkaline lakes and soils. Even now, fairly large quantities of natural soda are being produced chiefly in the U. S. A. (130,000 tons in 1940), and from Lake Magadi (50,000 tons per annum). But the quantities thus obtained form only a small proportion of the world's total output of soda ash.

In the LeBlanc process for the manufacture of sodium carbonate, patented in 1791, sodium chloride is converted into sodium sulphate by treatment with sulphuric acid. The latter is heated to a high temperature with limestone and coke to yield 'black ash'.

$$Na_2SO_4 + CaCO_3 + 2C \rightarrow Na_2CO_3 + CaS + 2CO_2$$

Sodium carbonate is leached out with water and purified by re-crystallization. In 1861, Ernst Solvay rediscovered the so-called ammonia-soda process, which has now almost entirely superseded the older process. Most of the world's present output of soda ash, estimated at 7 million tons per annum, is now manufactured by the Solvay process. The chief advantages of this process are the low cost of production, and the high purity of the carbonate.

In the Solvay process, a concentrated solution of common salt is saturated with ammonia and then with carbon dioxide, when ammonium bicarbonate is formed. This reacts with sodium chloride forming sodium bicarbonate and ammonium chloride :

$$NaCl + NH_4HCO_3 \rightarrow NaHCO_3 + NH_4Cl$$

$NaHCO_3$ is insoluble under the conditions of reaction and is precipitated out. This is filtered and calcined to yield Na_2CO_3.

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$$

Ammonia, recovered by distilling the residual liquor containing ammonium chloride with milk of lime, is again used in the cycle of operations.

Although the reactions involved in the Solvay process are comparatively simple, successful operation requires a high degree of technical skill and scientific training. A careful integration of various stages is necessary, especially as the process does not admit of any interruption. Most of the operations involve reactions between gases and liquids, and proper designing of the equipment is of the utmost importance, especially to prevent clogging of the passages, scale formation, and gas leaks, leading to loss of ammonia. Another vital factor on which production depends is the control of temperature at each stage of the various operations.

The chief raw materials for the manufacture of soda ash by the Solvay process are salt, limestone and ammonia. Small quantities of sodium sulphide are also necessary. The plant should be located within easy reach of raw materials and coal, and should have a large supply of good quality water.

Salt is used in the form of saturated brine prepared from either sea salt or rock salt, the latter being preferred on account of the smaller amounts of impurities in it (Rogers, I, 411; *vide* also Vakil, Salt, 1945). Natural brines and sea-water saturated by adding extra salt may be used directly, but in these cases purification of brine is an elaborate process.

Limestone furnishes carbon dioxide for carbonation, and lime for the recovery of ammonia and for the purification of brine. It should be of high grade (CaO. 85 per cent.), with only small amounts of magnesium carbonate (up to 6 per cent.), silica, aluminia, and iron oxide. This limestone is usually mixed with coke and burnt, the carbon dioxide (lean gas, CO_2, 40-43 per cent.) being collected separately for carbonation.

The ammonia requirements of the process are fairly large. The quantity of ammonia present in the system is 0.45 ton per ton of soda ash manufactured. But fortunately the losses are small.

CONSUMPTION OF RAW MATERIALS PER TON OF SODA ASH

Salt	1.50—1.75 tons
Limestone ..	1.20—1.35 ,,
Coke	0.095—0.11 ,,
Coal	0.41—0.75 ,,
Ammonia ..	4.94—9.88 lb. as $(NH4)_2SO4$
CO_2	1120—1344 c.ft.
Na_2S	0.0012—0.0024 ton

These figures apply only to large plants, and smaller plants are much less economical in the consumption of raw materials.

The first step in the Solvay process is the preparation of a saturated solution of sodium chloride, and the removal of calcium and magnesium compounds from it. For this, brine is treated with lime, ammonia and carbon dioxide, or with lime and soda ash. After clarification, the clear liquor is cooled and transferred to the ammonia absorber. Purification of brine may also be effected during the absorption of ammonia by passing in a small amount of carbon dioxide.

Since ammoniated brine has a corrosive action on iron, a small quantity of sodium sulphide is added to the ammonia still, and hydrogen sulphide liberated passes along with ammonia gas, and gives a coating of ferrous sulphide to all iron apparatus. Ferrous sulphide is inert in alkaline solutions.

During the absorption of ammonia, considerable heat is evolved, and also the volume of brine increases. Since rise in temperature increases the partial pressure of ammonia and decreases the quantity of ammonia in solution, the absorption tower is fitted with cooling coils. After the requisite amount of ammonia has been introduced, brine is allowed to settle, cooled to 25°, and pumped to the carbonating tower. At this stage it contains about 80 g. of ammonia and 260 g. of sodium chloride per litre.

Carbonation is carried out in a tall, cast-iron tower, nearly 75′ in ht. and 6-7′ in internal diameter. It is leakproof and is built of several compartments of special design, fitted tight to one another. Ammoniated brine fed from the top of the tower meets with a strong counter-current of rich carbon dioxide fed from the bottom at a pressure of about 30 lb. As the reaction proceeds, carbon dioxide is rapidly absorbed, 60 g. of ammonia per litre taking up 166 g. of CO_2 for conversion into the bicarbonate. Sodium bicarbonate separates out from solution in the form of fine crystals. The temperature rises to nearly 55-60° about half way down the tower. The crystals grow larger as the temperature gradually drops to 25° in the lower portions of the tower and form a slurry. This is drawn off periodically and filtered under vacuum on a rotary open-drum filter. The cake is washed with water to free it from salt and ammonium chloride, and fed to the calciner.

The towers become fouled after four days of operation, and the cooling tubes get coated with much sodium bicarbonate, which reduces their efficiency. The tower is cleaned by partial carbonation of ammoniated brine during 18-24 hrs. while the temperature is maintained at 38-40°. The brine dissolves all the sodium bicarbonate and is sent to another tower for further carbonation. It is usual to work with at least 4 columns, three of which are used for preparing sodium bicarbonate, while the fourth is being cleaned. Each tower produces the equivalent of 50-60 tons of soda ash per 24 hrs. Thus the minimum capacity of a plant for economic operation is 150-200 tons per 24 hrs.

The calcination of sodium bicarbonate is carried out in a rotary furnace. The chief difficulty in this operation is the caking of the bicarbonate. To reduce this, wet sodium bircarbonate is mixed with some hot soda ash, and the calciner is fitted inside with a heavy scraper chain, to break up any lump formed. The exit gases are chiefly carbon dioxide, and some ammonia, mixed with a large amount of steam. When these are cooled, ammonia liquor is formed, and the rich carbon dioxide left over, is returned to the carbonator.

After separation of the bicarbonate, the filtrate contains most of the ammonia used in the process, chiefly in the form of ammonium chloride, with small amounts of carbonate, bicarbonate, etc. This ammonia, since it is an expensive material, must be recovered completely for the economic working of the Solvay process. This is effected in a still, the upper part of which is heated. As the liquor flows down, carbonate and bicarbonate are decomposed, and further down the hot liquor meets with hot milk of lime, which decomposes ammonium chloride. The vapours leaving the top of the still consist of a mixture of ammonia, carbon dioxide and some steam.

The exhausted liquor contains about 50 g. per litre of residual sodium chloride, and calcium chloride. These are sometimes recovered, or run out with waste liquor. The loss of ammonia is 0.35-0.5 per cent. of sodium carbonate manufactured.

The hot soda ash is cooled and screened through 8-12 mesh, and the 'light ash' thus obtained is bagged. A denser form of 'heavy ash' is prepared by mixing light ash with a small quantity of water and redrying it in a rotary dryer. The minimum Na_2CO_3 content of soda ash prepared by the Solvay process is 98.5 per cent., and good grades contain up to 99.5 per cent. (Hou, Manufacture of Soda, 1942, 218).

When compared with industrially developed countries, India consumes only a small amount of soda ash. In '44, the estimated consumption in the U. S. A. was over 4 million tons, while in India it was only 107,500 tons. The target for production in the next 5 years set by the Heavy Chem. Industr. Panel (Rep. Heavy Chem. and Electro-Chem. Industr. Panels, 1947, 14) is only 270,000 tons. The distribution of soda ash among various consuming industries in the U. S. A. and in India in '44, and the estimated consumption in the near future in India are given in the following table :—

Industry	Consumption in '44		Five year target
	In U. S. A. (Tons)	In India (Tons)	(Tons)
Glass ..	1,148,000	25,000	50,000
Paper	142,000	12,000	24,000
Textiles ..	53,000	9,000	12,500
Dichromates ..	..	5,000	5,000
Sodium silicate ..	..	3,500	3,500

Industry	Consumption in '44		Five year target (Tons)
	In U. S. A. (Tons)	In India (Tons)	
Ordnance factories	..	3,000	3,000
Misc. chemical industries	912,000	2,000	4,000
Other industries	647,000	48,000	70,000
Caustic soda and bicarbonate	919,000	..	95,000*
Exports & misc.	356,000	..	..
	4,177,000	107,500	267,000

*For 57,000 tons of caustic soda.

Until '40, India's annual requirements of soda ash were met entirely by imports, chiefly from Great Britain. The average annual imports during the quinquennium ending '38-39 were 65,400 tons, valued at Rs. 60.18 lakhs.

In recent years, increasing quantities of natural soda are coming from Kenya Colony (30,000 tons in '43-44). This ash fetches a lower price, since it contains a small proportion of organic matter which discolours it, and also some impurities, especially iron, which render it unsuitable for use in the manufacture of white glass.

The first attempt at the manufacture of soda ash in India was made by the Sri Shakti Alkali Works, immediately after the first World War, at Dhrangadhra in Kathiawar. This, however, proved abortive and the factory closed down in '31. The Dhrangadhra Chemical Works, a new concern, purchased its assets just before the second World War, reorganised the works and went into production in '40. Their annual output is 18,000 tons of soda ash. The soda ash plant at Khewra (the Punjab) of the Alkali and Chemical Corporation of India, a subsidiary of the Imperial Chemical Industries (India), of capacity 20,000 tons per annum, began production in '45. Messrs. Tata Chemicals started the construction of a large plant of capacity 36,000 tons per annum at Okhamandal in '39. The outbreak of hostilities created exceptional difficulties and the effects of the war have hitherto hindered the successful development of this project. Thus, although the rated capacity of the three Indian plants is about 74,000 tons per annum, production has been much less. A rapid expansion in production is vital to India's industrial development.

The total investment in the Alkali industry in India (1945) is estimated at about Rs. 3 crores.

SODIUM BICARBONATE

Sodium bicarbonate, $NaHCO_3$, also known as baking soda, occurs in the form of a white powder or crystalline lumps (sp. gr., 2.20). It is soluble in water, but not in alcohol. Its aqueous solution has a saline taste and gives a feeble alkaline reaction. When heated, the dry substance begins to lose carbon dioxide at 250° and is converted into sodium carbonate.

Sodium bicarbonate is chiefly used for the preparation of carbon dioxide for aerated water. It is a constituent of baking powders and effervescent salts, and is used in fire extinguishers.

In medicine, the pure salt is administered in all cases of acidosis, biliousness, dyspepsia, and flatulence. It is also useful in bronchial catarrh and bronchitis, rendering the secretion less tenacious. A very weak solution (2 per cent.) is used as an eye lotion, and to relieve the irritation of urticaria and eczema.

Sodium bicarbonate is obtained as an intermediate product in the manufacture of soda ash by the ammonia-soda process. This crude product is difficult to dry and contains an appreciable percentage of ammonium bicarbonate (3-4 per cent.), which gives it an odour that renders it unfit for many uses.

For the preparation of sodium bicarbonate, carbon dioxide is passed into a saturated solution of calcined soda ash. The bicarbonate formed being insoluble under the prevailing conditions separates out from solution. The crystals are centrifuged and dried in a current of hot air. The finished product is usually 99.7-99.85 per cent. pure. It is packed in wooden barrels and casks for bulk transport, and in bottles and paper cartons for small packings.

The present consumption in India is about 6000-6500 tons per annum, internal production being only about 1500 tons. Imports are almost entirely from the U. K., and during the quinqennium ending '38-39 averaged 5800 tons per annum, valued at Rs. 6.36 lakhs. Messrs. Tata Chemicals (Okhamandal) have a plant for the manufacture of 10 tons per day of refined sodium bicarbonate.

SODIUM HYDROXIDE

Sodium hydroxide or caustic soda, NaOH, is a white brittle solid and occurs in the form of lumps or sticks (*d*, 2.13), which show a crystalline fracture. The usual impurities in it are sodium chloride and sodium carbonate. It may be purified by dissolving it in alcohol, in which the impurities are insoluble, and removing the solvent from the filtered solution. On exposure to air, sodium hydroxide rapidly absorbs moisture and carbon dioxide, and is converted into the carbonate. When heated, it begins to melt at 318° and volatalizes slowly at red heat. Solutions of sodium hydroxide are strongly alkaline, have a corrosive action on the skin, and destroy organic tissues. Caustic burns should be washed with dilute acetic acid or citric acid. Sodium hydroxide is readily soluble in water and alcohol.

Caustic soda attacks most of the common metals excepting nickel. It attacks iron at higher temperatures and concentrations.

Commercial caustic soda is marketed in the form of fused lumps, pellets, flakes, or powder, and is graded according to its sodium oxide content. The standard grade rated as 76 per cent. Na_2O contains 98 per cent. NaOH, the rest consisting of sodium chloride, sodium carbonate, sodium sulphate, etc. High grade alkali required for the manufacture of rayon should contain less than 1 per cent. of impurities.

A standardized 50 per cent. solution of sufficiently high purity, called 'liquid caustic', is now marketed in large quantities for direct use in many industries. Several manufacturing industries, especially paper factories, prepare their requirements of caustic alkali in their own works and use it directly in solution (NaOH, 12 per cent.).

Drums made of steel plates are used as containers for technical caustic soda, and steel tank cars are employed for transporting liquid caustic.

Caustic soda is usually manufactured either by the chemical (lime-soda), or by the electrolytic process. In the former, soda ash is treated with quicklime :

$$Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$$

In the latter, a saturated solution of salt is electrolysed :

$$2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$$

The simultaneous production of chlorine, in quantities nearly equal to those of caustic soda produced, limits the use of the electrolytic process to areas where there are adequate facilities for the economic disposal of chlorine.

Plants manufacturing sodium hydroxide by the chemical process are usually adjuncts to soda ash factories. A strong solution of soda ash (18-20 per cent.) is prepared by dissolving the ash in water, or by decomposing a solution of sodium bicarbonate from rotary filters (*vide* sodium carbonate) by boiling it with steam. This is charged to a causticizing tank provided with an agitator. A solution of milk of lime (250 g. CaO/l.) is gradually run in while the temperature is maintained at about 85° by means of steam. Agitation is stopped after an hour and the contents of the tank are transferred to a series of cylindrical settling tanks with conical bottoms. In the first of these, the precipitated calcium carbonate settles in an hour, and the clear liquor which contains about 12 per cent. NaOH is decanted. Recovery is generally over 99 per cent. Plants designed for continuous operation are of large capacity.

The precipitate is washed several times using the wash water in counter-current. Fresh water is employed only when it is nearly free from alkali. The calcium carbonate thus obtained is recalcined to yield quicklime, or it may be employed in the manufacture of cement.

The decanted lye is used directly in some industries such as paper-pulp manufacture. Its concentration is carried out in multiple-effect evaporators till it reaches about 50 per cent., and is allowed to cool. Most of the unreacted sodium carbonate, sodium chloride and other impurities separate out. The clarified liquor constitutes the ' liquid caustic ' of commerce.

Further concentration (up to 75 per cent.) is carried out in a single-effect nickel-coated evaporator. The liquor is then transferred to direct fired cast-iron fusion pots and heated till the temperature reaches 500°. After some time, it is allowed to cool down to 350°, when most of the remaining sodium carbonate, etc., are thrown out. The molten mass is ladled into drums, each capable of containing about 700 lb. of solid caustic soda. The mass solidifies on cooling and the drums are immediately sealed, in order to prevent absorption of moisture.

Sometimes, due to impurities, caustic soda in the pots is found to be coloured dark-green or slightly reddish. The colour is improved by sprinkling over the surface a small quantity of sulphur, before it cools down to 400°.

2900 lb. of soda ash and 160 lb. of make-up lime (CaO, 90 per cent.) are required for the production of 2000 lb. of caustic soda (11 per cent. solution) in a plant of capacity, 89.3 tons per day. The efficiency of conversion is about 98 per cent. Caustic soda produced by the lime-soda process is of a high degree of purity and is suitable for use in rayon manufacture. Good quality caustic soda produced by this process has the following analysis (Hou, *loc. cit.*, 295) : NaOH, 98.70 ; Na_2CO_3, 0.60 ; NaCl, 0.30 ; Na_2SO_4, 0.20 and water and undetermined substances, 0.20 per cent.

In the manufacture of electrolytic caustic soda, purification of brine is the first stage. Saturated brine prepared from rock salt or solar salt contains small amounts of calcium and magnesium salts (chlorides and sulphates). Calcium, and most of the magnesium are precipitated as carbonates by the addition of requisite quantities of soda ash, and the remaining magnesium, as hydroxide by the addition of slaked lime, or caustic soda residues. Sulphate ions are eliminated by means of barium chloride and the brine is heated to 60° to facilitate the settling of the precipitate. After filtration it contains 25 per cent. of sodium chloride. To correct its alkalinity a small amount of hydrochloric acid is added before it is sent to the cells. Apart from facilities available for the disposal of chlorine, the availability of cheap salt and electric power determine the suitability of the electrolytic process for any particular region.

The cells which are in general use at

present are of two types : mercury cells, and diaphragm cells. In mercury cells, the cathode consists of mercury and the anodes are made of rods of graphite. During electrolysis, sodium is amalgamated with mercury, and chlorine is liberated at the anode. The amalgam is decomposed by pure water in a separate compartment, resulting in the formation of pure sodium hydroxide and hydrogen. The quantity of water is so regulated as to result in the direct production of caustic soda of up to 50 per cent. concentration. The mercury cells run at high current densities, with a current efficiency of nearly 95 per cent. The operating voltage is 4-5 volts per cell and 1.6 Kw.-hr. of power are required for the production of 1 lb. of caustic soda.

Mercury cells have the advantage of a high output (4-16 cwt. per day) of pure caustic soda of high concentration, free from sodium chloride and other impurities. The original Castner cell has undergone numerous modifications. One of these, the Krebs cell, takes as much as 15,000 amps. per cell and is capable of a very large output. But the initial investment is high owing to the cost of mercury.

The development of diaphragm cells has received the greatest attention in the U. S. A. In these cells, the tank is made of either mild-steel or concrete, and an asbestos diaphragm separates the electrodes, and prevents the admixture of cathode liquor and chlorine, without arresting the flow of brine from the anode to the cathode. For high energy efficiency, the anodes are placed as near the cathodes as possible, the electrode surface is made large and the electrolyte is kept hot. To prevent excessive anode losses, electrolysis is stopped when about half the sodium chloride in the brine is converted to caustic soda. The diaphragm allows ions to pass through by electrical migration, but reduces the diffusion of products. The flow of brine from the anode to the cathode inhibits the secondary reaction resulting in the formation of sodium hypochlorite and chlorate.

The standard Vorce cell consists of a cylindrical steel cell tank 26″ in diameter and 42″ in height. Inside the tank are a perforated iron sheet cathode, and an asbestos sheet diaphragm, both cylindrical in shape. The anode assembly consists of a circular row of 24 graphite rods of 2″ × 2″ square section and 36″ length. Several units are operated in series, and current efficiency is 95 per cent.

The Hooker ' S ' type cell is the latest and the most advanced type of diaphragm cell. The external dimensions of the cell are by 5′ × 4′ 6″ × 3′ 8″. The cell, which is cubical in shape, consists of a concrete top piece, a concrete bottom and a central steel frame which carries a unique finger-type of cathodes. These are made from crimped steel wires and are inserted between the anodes. The cathodes are directly covered with asbestos which forms the diaphragm, and are completely immersed in brine. The cathode assembly also carries outlets for hydrogen and caustic alkali. The anode assembly consists of 30 graphite blades set in a bitumen covered lead base plate. The cell operates at a temperature of about 85°, has a large production capacity and high electrical current efficiency (97 per cent.).

The operating data for the Vorce and Hooker ' S ' type cells are given below :—

	Vorce cell	Hooker ' S ' type cell
Current per cell ..	1000 amps.	7500 amps.
Voltage across cell ..	3.5 volts	3.4 volts
Power consumption/lb. Caustic soda	1.15 Kw.-hr.	1.1 Kw.-hr.
Caustic soda produced...	72 lb/day	5 cwt./day
Chlorine ..	64 lb./day	4.52 cwt./day
NaOH content of cell liquor	8.5 per cent.	12 per cent.
NaCl content of cell liquor	16 per cent.	14 per cent.

Since the conversion efficiency of diaphragm cells is only about 50 per cent., the effluent contains 8-12 per cent. NaOH and 14-18 per cent. NaCl. The liquor is concentrated in double—or triple—effect evaporators till the concentration of alkali reaches 50 per cent. and is allowed to cool. Most of the sodium chloride crystallizes out at this stage, owing to its insolubility in strong alkali. This is separated, washed, till it contains only 0.1 per cent. NaOH, and its solution is used for the purification of raw brine.

The 50 per cent. caustic liquor after the separation of sodium chloride, etc., still contains about 1 per cent. NaCl. This liquor (liquid caustic) is suitable for most purposes, and over 50 per cent. of electrolytic alkali is marketed in this form. To obtain solid caustic soda, liquid caustic is further concentrated in a single-effect evaporator till the concentration reaches 70-75 per cent., and is subsequently heated in direct-fired caustic fusion pots. The caustic soda thus produced contains about 2 per cent. NaCl.

Methods have been developed for the further purification of caustic soda from diaphragm cells. In one, liquid caustic is diluted to 35 per cent. and cooled to 3°, when pure sodium hydroxide crystallizes out in the form of $NaOH. 3\frac{1}{2}H_2O$. These are separated and converted into anhydrous NaOH. In another recently developed method, liquid caustic is washed with a counter-current of anhydrous ammonia when chemically pure crystals of anhydrous NaOH separate out.

The chlorine obtained as a by-product is cooled, dried, condensed and filled into cylinders or tanks. The hydrogen produced is made use of for various hydrogenation processes or for the preparation of synthetic ammonia, hydrogen chloride, etc.

Owing to limited demand for chlorine, the world production of chemical caustic soda was in excess of electrolytic soda till about '40. The chemical process is worked as an adjunct to soda ash factories and yields a product of very high purity containing over 98.7 per cent. NaOH with less than 0.3 per cent. NaCl. The process has the additional advantage that it has no problems connected with the disposal of by-products.

The electrolytic caustic industry made phenomenal progress during the War and enabled the rapid stepping up of production. Owing to shortage of mercury, most of the developments were with diaphragm cells. These cells yield alkali of low concentration, and an elaborate process of purification is necessary to concentrate the liquor, and to purify it. Recent developments in Germany in the design of mercury cells are likely to bring them into greater prominence in the production of caustic soda in the future. The production of electrolytic soda is limited only by the demand for the chlorine which is simultaneously produced.

Caustic soda is one of the basic heavy chemicals indispensable to a number of industries such as the manufacture of rayon, soap, paper, chemicals, oil refining, and the textile industry. Although it is nearly 2½ times as costly as soda, immense quantities are produced and consumed in all industrially advanced countries. In '44, the U. S. A. produced 1,894,600 short tons of caustic soda (689,600 tons of lime-soda and 1,205,000 tons of electrolytic soda), and the consumption in that year is estimated to have been distributed thus (*Chem. Engng.*, 1947, **54**, *ii*, 111) :

	Short tons
Soap	125,000
Chemicals	390,000
Petroleum refining	140,000
Rayon, staple fibres and cellulose film ..	345,000
Lye and cleansers	110,000
Textiles	110,000

	Short tons
Rubber reclaiming	25,000
Vegetable oil	18,000
Pulp and paper	100,000
.. .. ..	521,000
Total ..	1,884,000

The present annual Indian requirements of caustic soda are estimated at only 54,000 tons, and the Heavy Chem. Industr. Panel (Rep., *loc. cit.*, 18) has placed the five-year target for production at 103,000 tons per annum :

	Present consumption (Tons)	Five-year target† (Tons)
Soap	23,500	52,000
Textiles	15,400	21,000
Paper	9,000*	18,000
Misc. including oil refining, etc.	6,000	12,000
Total ..	54,000	103,000

* This is in addition to the alkali produced by many Indian paper mills (estimated at 14,000 tons per annum, Thomas, Rep. Develop. Industr. War Supplies, 1944, 28), for consumption in their works.

† The target does not include the alkali required for rayon manufacture.

Before '40, the entire quantity of caustic soda consumed in India was imported, chiefly from the U. K. The average annual imports during the quinquennium ending '38-39 amounted to 22,300 tons, valued at Rs. 41.64 lakhs. There are now three concerns in India producing caustic soda with a total capacity of 12,000 tons per annum.

CAUSTIC SODA PLANTS IN INDIA

	Location	Production commenced in	Annual production capacity (Tons)	Remarks.
The Tata Chemicals	Mithapur	..	8,800	6,000 tons of alkali by the lime-soda process and 2,800 tons by the electrolytic process. Production so far has been intermittent and very much below capacity.
The Alkali & Chemicals Corporation	Rishra (Calcutta)	1940	1,600	Sold to consumers in the form of 48 per cent. solution.
The Mettur Chemical & Industrial Corporation	Mettur	1941	1,600	NaOH sold in sticks and flakes. Product contains 4 per cent. NaCl.

Hitherto, the quantity produced by the factories has not exceeded 3,000 tons in any one year. According to the estimates of the Tariff Bd. (Rep. Caustic Soda and Bleaching Powder Industry, 1946, 13), pro-hyplen duction is expected to reach 11,730 tons in '48-49. Thus the major portion of caustic soda used in the country has still to be imported.

Imports of caustic soda are subject to a duty of 36 per cent. *ad valorem* and a preferential rate of 24 per cent. *ad valorem*. The landed cost of caustic soda including duty at present (1946) is estimated at Rs. 15-10 per cwt. while the fair selling price per cwt. of the product manufactured by the Mettur Chemicals is estimated at Rs. 17-10 during the period Oct.'46-Dec. '47. This is expected to go down to Rs. 15-9 per cwt. after Jan. '48. The Tariff Bd. was not in favour of an increase in duty on a basic chemical which has to be imported in large quantities. Their proposal to grant a subsidy of Rs. 2 per cwt. for all the caustic soda manufactured and sold by the Mettur Chemicals during the period mentioned above has been accepted by the Government.

Caustic soda in the form of flakes or powder fetches a higher price, usually about Rs. 2 per cwt. than the fused variety.

Plans have been made for a rapid expansion in the production of electrolytic caustic soda by the installation of a number of small plants (5 tons/day) in various consuming centres throughout the country, and production in the future is expected to reach 35,600 tons per annum. The new plants have been sanctioned only on the basis of showing use for chlorine which is simultaneously produced. They represent the saturation point for the use of chlorine at the present stage of Indian industrial development. Consequently, in order to attain self-sufficiency with respect to caustic soda, India will have to manufacture a large proportion of her requirements by causticising soda ash, and the production of the latter will have to be stepped up correspondingly.

AVERAGE ANNUAL IMPORTS OF ALKALIS INTO BRITISH INDIA

(Qty. in 1000 tons and val. in lakhs of Rs.)

	Soda ash		Sodium bicarbonate		Caustic soda	
	Qty.	Val.	Qty.	Val.	Qty.	Val.
In quinquennium ending—						
'33-34 ..	48.0	56.8	5.3	8.1	12.8	129.9
'38-39 ..	55.1	65.2	5.8	6.4	22.3	41.6
'43-44 ..	71.1	84.3	5.1	7.9	32.0	82.0
In '44-45 ..	50.8	75.9	4.6	10.2	42.2	130.5
.. '45-46 ..	78.9	122.8	4.7	11.0	37.9	116.7

CUSTOMS DUTY AND PRICES

	Customs duty *ad valorem*		Valuation for tariff purposes* (Rs./cwt.)		Market rates† in Jan. '47 (Rs./cwt.)		
	Standard rate	Preferential rate	'39	'44	Calcutta	U.K.	U.S.A.
	Per cent.	Per cent.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
Soda ash ..	30	18	4 8	9 0	11 4	5 6	3 8
Sodium bicarbonate ..	36	24	4 8	12 0	14 4	7 6	6 11
Sodium hydroxide ..	36	24	8 0	20 0	19 0	10 0	4 7

* *Indian Customs Tariff.*

† *Indian chem. Mfr. Ass., News sheet,* 1947, **1**, No. 1, 8.

POTASH AND CAUSTIC POTASH

Potash or potassium carbonate, K_2CO_3, is a constituent of wood ashes. Ray gives the following analyses of the ashes of some plant materials (*Proc. nat. Inst. Sci. India,* 1943, **9**, 143) :

	K_2O (per cent.)
Sun-flower stem	36—37
Chrysanthemum tegetum	24—25
Cotton husk	10—42
Banana stem	46—64
Bamboo shoots	32—33

Potash is manufactured from potassium chloride or potassium sulphate. The anhydrous salt is a strong dehydrating agent. It is employed for the preparation of potassium salts and in the manufacture of special glasses. Potassium bicarbonate, $KHCO_3$, is formed, when carbon dioxide is passed through a strong solution of the carbonate. It is less soluble in water than sodium bicarbonate.

Caustic potash or potassium hydroxide, KOH, is very similar to sodium hydroxide. It is prepared by the electrolysis of potassium chloride, or by treating potassium carbonate with milk of lime. Potassium hydroxide is used in the manufacture of soft soap.

Before the War, India's requirements of these potassium compounds were met by imports, mainly from Germany, Holland, and France.

ALUMINIUM

Aluminium is the most abundantly occurring metallic element being even more plentiful than iron. However, it never occurs free, but is always found in the combined state. It was first isolated in 1825 by Oerstedt, and was comparatively rare till 1886, when the electrolytic process for its preparation was discovered simultaneously by Hall in America, and by Heroult in France. Since then it has rapidly attained the position of a major industrial metal. World production, which in '29 was 270,100 metric tons, rose to 672,400 metric tons in '39. In the latter year, Germany was the leading producer with an output of 200,000 metric tons.

During the last War ('39-45), world production reached a peak of 1,926,000 metric tons in '43 to meet the military demands of the belligerent powers. Expansion in production was most marked in Canada and the U. S. A. Since the War, there has been a rapid decline in output, and it came down to 916,000 tons in '45. At present, United States, Canada and the U. S. S. R. are the major producers.

WORLD PRODUCTION OF ALUMINIUM IN 1945*

(In thousand metric tons)

Canada	195.7
U. S. A.	450.4
U. S. S. R.	86.3
France	37.2
U. K.	32.4
Others	114.0
Total	916.0

Aluminium is a silvery white metal (m. p., 660°), the main characteristic of which is lightness combined with strength. It gives a wide range of extremely valuable alloys with a number of elements, chiefly, copper, magnesium, manganese, nickel, and silicon. These alloys have lower melting points than the pure metal.

Aluminium has a sp. gr. of 2.7 (wt., 169.2 lb. per c. ft.) as against 7.84 for steel, and 8.89 for copper. It is capable of taking a high polish, and is an excellent conductor of both heat and electricity, its electrical conductivity being about 62 per cent. of that of copper. Its coefficient of linear expansion is 24×10^{-6} and modulus of elasticity, 9.9×10^{6} lb./sq. in. The tensile strength may vary from 5 tons per sq. in. for soft, high purity metal, to 30-36 tons per sq. in. for some of its alloys. Pure aluminium is a comparatively soft metal and its Brinell hardness (10 mm. ball, 500 kg., 30 sec.) is 25, but may be raised to about 40 by annealing and cold work. Its alloys are much harder, their Brinell hardness varying from 40 to nearly 90 (Liddell, Handbook of Non-ferrous Metallurgy, II, 1945, 24).

Chemically aluminium is a reactive metal. It combines directly with a number of elements under suitable conditions. It has a great affinity for oxygen, and aluminium foil or powder can be burnt in air. However, at ordinary temperatures, aluminium is comparatively stable when exposed to atmosphere. This is due to the formation of a thin protective coating of the oxide on its surface. Aluminium is electro-positive to most of the common metals, such as, iron, silicon, copper, and, consequently, undergoes corrosion, due to electrolytic action, when it comes into direct contact with them in the presence of moisture.

Aluminium is attacked in varying degrees by many mineral acids especially in the dilute state, and is also attacked by several organic acids. However, it is unaffected by pure, cold nitric acid, dilute or concentrated. The metal is readily dissolved by caustic alkalis and is corroded by solutions of chlorides and mild alkalis.

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* *Miner. Yearbook*, 1945, 697.

The commercial ore of aluminium is bauxite (q. v.), in which aluminium is present as hydrated oxide. Bauxite occurs in the form of moderately dense rock, often pisolitic in structure. Its colour depends upon the amount of iron oxide present, and may be white, grey, pink or brown. It varies widely in composition, and bauxite for aluminium manufacture should contain a minimum of 52 per cent. of Al_2O_3, and not more than 5 per cent. SiO_2, 10 per cent. Fe_2O_3, and 10 per cent. TiO_2. The usual grades contain : Al_2O_3, 55-60 ; SiO_2, 2-3 ; Fe_2O_3, 3-10 ; and TiO_2 up to 10 per cent. Where alumina works are not close to bauxite deposits, freight is usually the major item in the cost of ore, and in considering the utilization of any particular deposit, its composition, cost of mining, and transport have to be taken into consideration.

During World War II, considerable developments were made in Germany and in the U. S. A. in the production of alumina from clay and low-grade bauxite ores.

The production of aluminium is carried out in two distinct and well-defined stages. The first is the elimination of impurities in bauxite by chemical means, resulting in the separation of the pure aluminium oxide (alumina). The second is the reduction of alumina to metallic aluminium in electrolytic reduction furnaces.

The first practical process for the production of alumina from bauxite was developed by Bayer in 1888. In this, the ore is crushed and calcined to remove water and organic impurities and ground to fine powder (100 mesh or finer). It is then digested for 2-8 hrs. in autoclaves with caustic soda solution (sp. gr., 1.45), with steam led in at 50-70 lb. pressure. Nearly 90 per cent. of alumina goes into solution forming sodium aluminate, $Na_2Al_2O_4$, while ferric oxide, titania, etc., remain undissolved, and silica is precipitated as sodium aluminium silicate. The liquor (sp. gr., 1.23) is blown into large settling tanks, and the impurities separate out as 'red mud'. It is then somewhat diluted and passed through filter presses. The clear sodium aluminate solution is pumped to large precipitating tanks, and 'seeded' with a small amount of precipitated aluminium hydroxide from a previous batch. About 70 per cent. of the dissolved aluminium hydroxide separates out in a nearly pure state during 36 hrs., and the rest on further standing. The precipitate is drawn off from the bottom of the tank, washed, filter-pressed and calcined at about 1000°, to yield anhydrous alumina in the form of finely divided white crystalline powder, containing approx. 99.3 per cent. of Al_2O_3.

Sodium hydroxide solution from the tanks is concentrated in vacuum evaporators and used again for the treatment of bauxite. The red mud forms a source of titanium (q. v.).

In the electrolytic process, alumina is dissociated by the electric current :

$$Al_2O_3 = 2Al + 3O$$

The electrolyte consists of fused cryolite (natural or synthetic), and calcium fluoride. Usually it corresponds to the formula, $2AlF_3 . 6NaF . 3CaF_2$. The purpose of calcium fluoride is to lower the fusion point of cryolite from 995° to about 700°. The electrolyte is capable of dissolving up to 20 per cent. of alumina, but during the electrolysis the concentration of alumina is usually maintained at 2-6 per cent. so that the density of the electrolyte is about 2.095.

The electrolytic cell consists of a rectangular steel box usually 8′ × 4′ × 4′.

This is lined inside with refractory material, covered by a thick layer of petroleum coke which forms the cathode. The anodes consist of specially prepared carbon electrodes fixed to a frame and arranged so that they may be lowered within 2″ of the molten layer of metal at the bottom of the furnace. Collector bars are embedded in the carbon lining and anodes to act as conductors of electricity.

The amperage of each cell varies from eight to ten thousand, and the cell operates at 5.5-7 volts. Consequently to get a workable voltage, it is usual to operate a number of cells in series. When starting, cryolite or a prepared bath material is charged into the cell and melted down by lowering the electrodes. When the cell is nearly filled with the molten bath, alumina is added at the top, and the electrodes raised into position. The resistance of the cell maintains the bath in the molten condition, and the aluminium formed, because of its higher density (2.29), collects at the bottom, and is drawn off at intervals, and poured into ingot. The metal is remelted to remove occluded bath salts, and cast into pigs. From time to time alumina is added to the cell to make the process continuous.

A cell of the dimensions mentioned yields about 120 lb. of aluminium per day and current consumption varies from 8 to 13 kw.-hr. per lb. of aluminium.

The anodes are made of petroleum coke of high purity (ash, 0.3 per cent.), because any impurity present in them will get into the metal. These anodes are continually oxidized by the liberated oxygen, which also keeps the bath well stirred. Electrode consumption is 0.6-0.8 lb. per lb. of aluminium.

Continuous self-baking Söderberg electrodes are now being used in the aluminium industry. These are made of hollow aluminium cylinders suspended above the furnace, with perforations to allow the escape of gases. The electrode mixture is fed into the cylinders and baked by the heat of the furnace. The cylinder and the electrodes are consumed as electrolysis progresses, and fresh sections are welded at the tops of cylinders when necessary. The electrode assembly is so arranged that current is fed into the furnace at all times, thus making the operation continuous.

Aluminium thus manufactured is over 99 per cent. pure. Purer material (Al, 99.8 per cent.) can be prepared by using Hoopes cells. In these there are 3 horizontal layers. The lowest is a liquid aluminium-copper alloy which forms the anode. Above this floats a layer of fused cryolite-barium fluoride (the electrolyte), and on the top is the cathode of pure liquid aluminium. The cell operates at 6 volts and 20,000 amps. Pure aluminium is dissolved from the anode and deposited on the cathode. from which it is tapped.

The electrolytic process consumes large quantities of electricity and hence an abundant supply of cheap power is essential for aluminium extraction. The greatest expansion in the production of aluminium has taken place in the U. S. A. and Canada, owing to vast development of hydro-electric projects. The latter country extracts the metal from ore imported from British Guiana. According to Heavy Chemicals and Electro-Chem. Industr. Panels Rep. (1947), the following are the quantities of raw material and power required for the production of 1 lb. of aluminium :

	Lb.
Bauxite	4.0
Caustic soda	0.15
Cryolite	0.05
Aluminium fluoride	0.03
Fluorspar (Calcium fluoride)	0.01
Petroleum coke	0.65
Pitch	0.07
Coal	3.50
Electric power	10 kw.hr.

The aluminium ingot thus produced must be fabricated to forms used by manufacturers, such as, sheets, foils, castings, forgings, extrusions, and powder. For making sheets, the metal is first cast into rectangular blocks for rolling, which are preheated, and then hot-rolled to slabs, $\frac{1}{4}''$-$\frac{1}{2}''$ thick. These slabs are then sheared to size, and cold-rolled to the desired thickness. Since aluminium hardens with cold-working, annealing at a temperature of approx. 350° is necessary at intervals before further rolling can be continued. The production of foil (0.005″ or less in thickness) is a continuation of the strip rolling process, in which rolls are ground to a fine finish, and narrow mills of extreme accuracy are used. Aluminium powder for use as paint is produced by stamping or milling aluminium shot or sheet clippings with a suitable lubricant (stearin and talc).

Commercial grade of aluminium is generally about 99.0 per cent. pure, with iron and silicon as the usual impurities, and is used for all purposes where high strength is not essential. Since the metal hardens with cold-working, it can be obtained in various tempers from soft to full hard, by a combination of annealing and rolling. Pure aluminium is extensively used in the manufacture of household cooking utensils and numerous domestic appliances and fittings. The metal and its salts are non-poisonous, and aluminium vessels are resistant to corrosion by several foods cooked in them. Aluminium is also employed for the manufacture of equipment for the chemical industry, the food industry, breweries and dairies.

Aluminium possesses high ductility. It can be drawn out into fine wires or beaten into very thin leaves. Aluminium foil is used for wrapping tobacco, coffee, tea, cheese, etc. The metal has also high electrical conductivity, and electric cables of hard-drawn aluminium wire are now replacing copper cables. In order to give them the necessary tensile strength, aluminium wires are reinforced by winding them over a stranded steel cable core.

Aluminium paints are made by mixing aluminium powder (200 mesh) with drying oils, spirit varnish, synthetic resins, etc. These paints are extensively used both as protective and decorative coatings for metals, wood, etc. Such coatings also act as excellent light and heat reflectors.

Aluminium powder is also used in the Thermit process for welding and repairing iron and steel parts. Thermit consists of a mixture of 3 parts of red oxide of iron with 1 part of aluminium powder. When ignited, the temperature may reach 2500°, and the heat generated produces molten iron. Aluminium powder is also used in metallurgy for the reduction of the oxides of chromium, manganese, titanium, etc.

Aluminium does not cast readily in the pure state, but when suitably alloyed it is extensively used in the form of castings. Casting processes include sand casting, gravity casting in permanent cast-iron moulds, and pressure die casting. Aluminium is plastic at working temperature, and can be readily forged, while its physical properties improve with working. Forging is usually carried out in steel dies by forging hammers or presses. Since aluminium is plastic at relatively low temperatures, it is also well-adapted to the extrusion process, in which a preheated billet is forced through a suitably shaped die opening in a powerful hydraulic press, producing long extrusions of intricate cross-section.

Aluminium finds its largest use in the form of alloys, and the greatest development during the past thirty years has been in the field of heat-treated alloys. The most extensively used wrought alloy of aluminium is duralumin (Cu, 4.0 ; Mg, 0.5 ; Mn, 0.5 ; Si, 0.25-0.6 per cent.). It is available in all forms, sheets, bars, girders, forgings, etc. It is the strongest aluminium alloy that can be produced by age-hardening at room temperature. On heat treatment, by quenching it from 500° in water, and allowing it to age at room temperature, it acquires a maximum tensile strength of 60,000 lb. per sq. in., with an elongation of 18-20 per cent., and becomes comparable to low carbon steel. Its density (2.8) is about 1/3 that of steel (7.9). It has high strength-to-weight properties and is extensively used in automobile and aircraft construction.

The prominent casting alloys of aluminium contain copper (8 per cent.) or silicon (12 per cent.), and also magnesium. Magnesium alloys have low density, and possess higher tensile strength than other aluminium casting alloys. Besides, magnesium renders the alloys resistant to corrosion and tarnish. Birmabright (Mg, 3.5-5.0 ; Mn, 0.5 per cent.) is used for the outer plates of small boats. Aluminium-nickel alloys (Ni, 4.5 per cent.) are used for die castings.

Casting alloys, containing 3 or 4 alloying elements, are used for special purposes. The Y-alloy [Cu, 4.0 ; Ni, 2 ; Mg, 1.5 ; Si (max.), 0.6 ; Fe (max.), 0.06 per cent.] is widely used for casting cylinder heads and pistons of aeroplane engines, and has good strength at elevated temperatures.

In recent years several high strength alloys, used as wrought alloys and as cast alloys, called R. R. alloys (Rolls Royce), containing Cu, Ni, Mg, Fe, Ti and Si, as alloying constituents, have been produced commercially by High Duty Alloys Ltd. of England. These are used for the construction of aeroplane engines.

Aluminium bronzes are alloys of copper, containing up to 11 per cent. of aluminium. They have high tensile strength and hardness, and show marked resistance to corrosion, but they are somewhat difficult to cast.

Aluminium and aluminium alloys can be readily welded either by the oxy-acetylene process or by electric resistance welding. In the case of heat-treated alloys, these must be heat-treated after welding, if strength is to be retained. Alternatively, jointing may be effected by rivets of the same alloy. Aluminium machines readily with ordinary metal cutting tools, and high machining speeds are obtained.

An electro-plated coating of nickel or chromium can be given to aluminium, after suitable preparatory treatment. However, where maximum resistance to corrosion and surface hardness is required, aluminium is usually given an anodising treatment, by an electrolytic process in a chromic or sulphuric acid bath. This gives a hard corrosion-resistant surface, and since the resultant film is slightly porous, an attractive surface finish can be given by the use of aniline dyes. Another protective treatment, the " Alclad " process, widely used in the case of strong alloys, consists in rolling over an outer coating of pure metal, a core of strong alloy sheet, the former giving complete protection against corrosion.

Tremendous expansion has taken place in the application of aluminium and its alloys during the past twenty years. Modern aircraft are constructed almost entirely of high-strength light-weight aluminium alloys. Fuselage and wings are constructed of extruded shapes, the covering being of sheet. Medium strength alloys are used for cowlings, fairings, petrol tanks, etc. Aluminium alloy forgings are used for wing attachments and under-carriages, and in the case of aircraft engine for crank cases, pistons, cylinder heads, connecting rods, and airscrew blades. In automobile engineering, apart from its use for pistons, cylinder heads, connecting rods, etc., extruded and sheet products are widely used for bus and lorry bodies, and for tanks, for the transport of petrol and other liquids. Aluminium is also extensively used in the construction of new high-speed streamlined trains, and for window-frames and interior fittings. The most familiar application in electrical engineering is in the form of cable for overhead transmission lines. Aluminium is also widely used in radio engineering and in the construction of radio sets. Another increasing use is in architecture, for such purposes as grilles, railings, window-frames, and for interior decoration.

Although the fabrication of aluminium utensils in India commenced in '12, extraction of the metal began only in '43. India possesses abundant deposits of bauxite of good quality, estimated at 250 million tons. Large deposits, in which mining development has already taken place, exist near Katni (C. P.), Ranchi (Bihar), and at Tungar Hill (Thana dist., Bombay), and near Belgaum. Other deposits, which have not been commercially developed, as yet, are in Kashmir, Kolhapur, in the Eastern States Agency, and near Salem in Madras (*vide* Bauxite).

The other raw materials, except coal, are required only in small quantities. Of these, petroleum coke is available from the oil refineries at Digboi in Assam, and pitch from the coke ovens and coal-tar refineries of Bengal and Bihar. The rest are mostly imported. Fluorspar mined in India is of low purity and is not suitable for aluminium production.

Just before the last War, two companies were established almost simultaneously for the extraction and fabrication of aluminium in India, with an authorized capital of nearly Rs. 4 crores. One of these, the Indian Aluminium Co. (I. A. C.), a Canadian sponsored concern, with alumina works at Muri (Bihar), reduction works at Alwaye in Travancore, and rolling mills at Belur near Calcutta, has been producing aluminium since Mar. '43 and converting it into sheets and circles. Its rolling mills are now being expanded for the production of strong alloys, such as duralumin. The Aluminium Corpn. of India (A. C. I.), with all their works at Asansol, in the Bengal coalfield, began production in '44. The combined capacity of these two works, when fully developed, is stated to be 8,000 tons of aluminium per annum.

The progress of the aluminium industry in India is linked with the development of hydro-electric power. So far the production of the metal has been low, and the chief difficulties are lack of sufficient quantities of cheap power, and high freight charges on internal movement of raw materials.

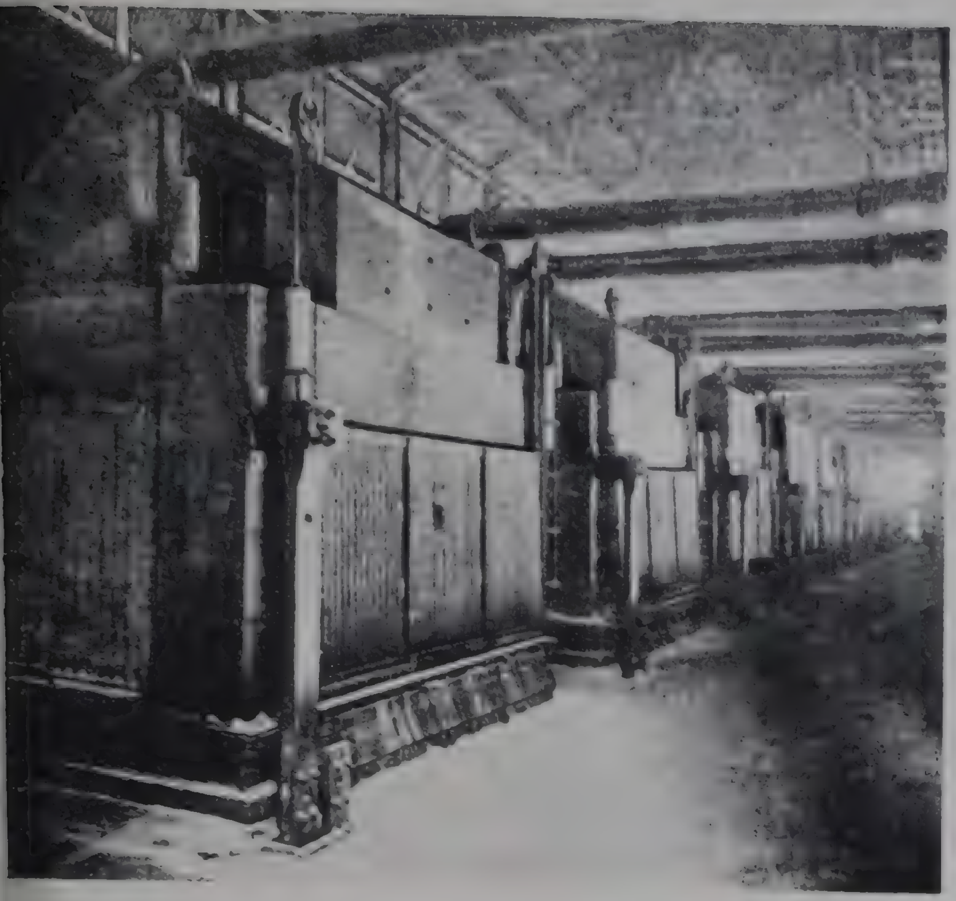
The I. A. C. began production of aluminium using imported alumina. The A. C. I. started the manufacture of alumina in India, in '44, from bauxite mined near Ranchi. Since July '44, a duty of 36 per cent. *ad valorem* has been imposed on imported alumina. The alumina works of the I. A. C. came into operation in '48, using bauxite from deposits near Lohardaga (Bihar). They have also mining leases on deposits near Belgaum.

PRODUCTION CAPACITY OF INDIAN ALUMINIUM WORKS (Tons)

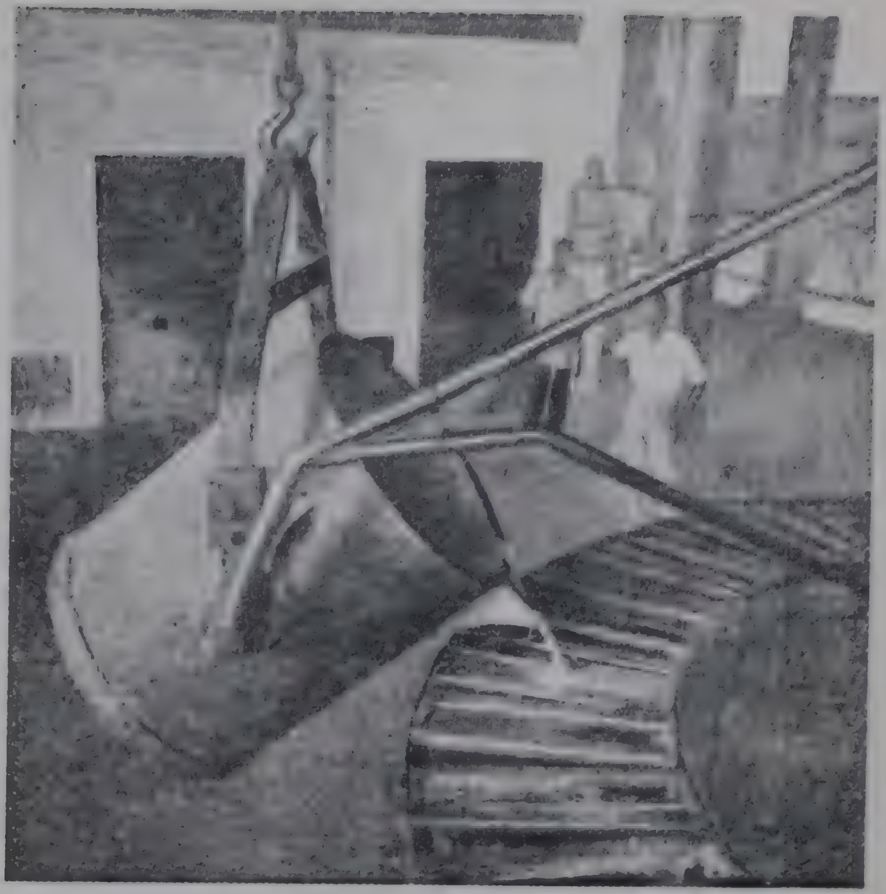
Company	Reduction Works				Alumina Works	
	Source of Power	Capacity	Output	Capacity for expansion	Capacity	Capacity for expansion
I.A.C.	Travancore State Hydroelectric Works (Pallivasal)	2,500	1,600	Up to 5,000	10,000	20,000 rising up to 40,000
I.A.C.	Coal	3,000	900	. .	4,000	6,000

The fabrication of aluminium sheets, circles, etc., is a well-established industry in India. Both the companies producing aluminium have their own rolling mills. In addition, a number of brass rolling mills also produce aluminium sheets. Recently Messrs. Venesta Ltd. (Calcutta) have begun the production of aluminium foil for lining tea-chests, and the Aluminium Industries Ltd. (Trivandrum) have erected a plant for the production of aluminium cable. The Indian Aluminium Co. are arranging to produce strips and foils and duralumin sheets in their works at Belur, near Calcutta.

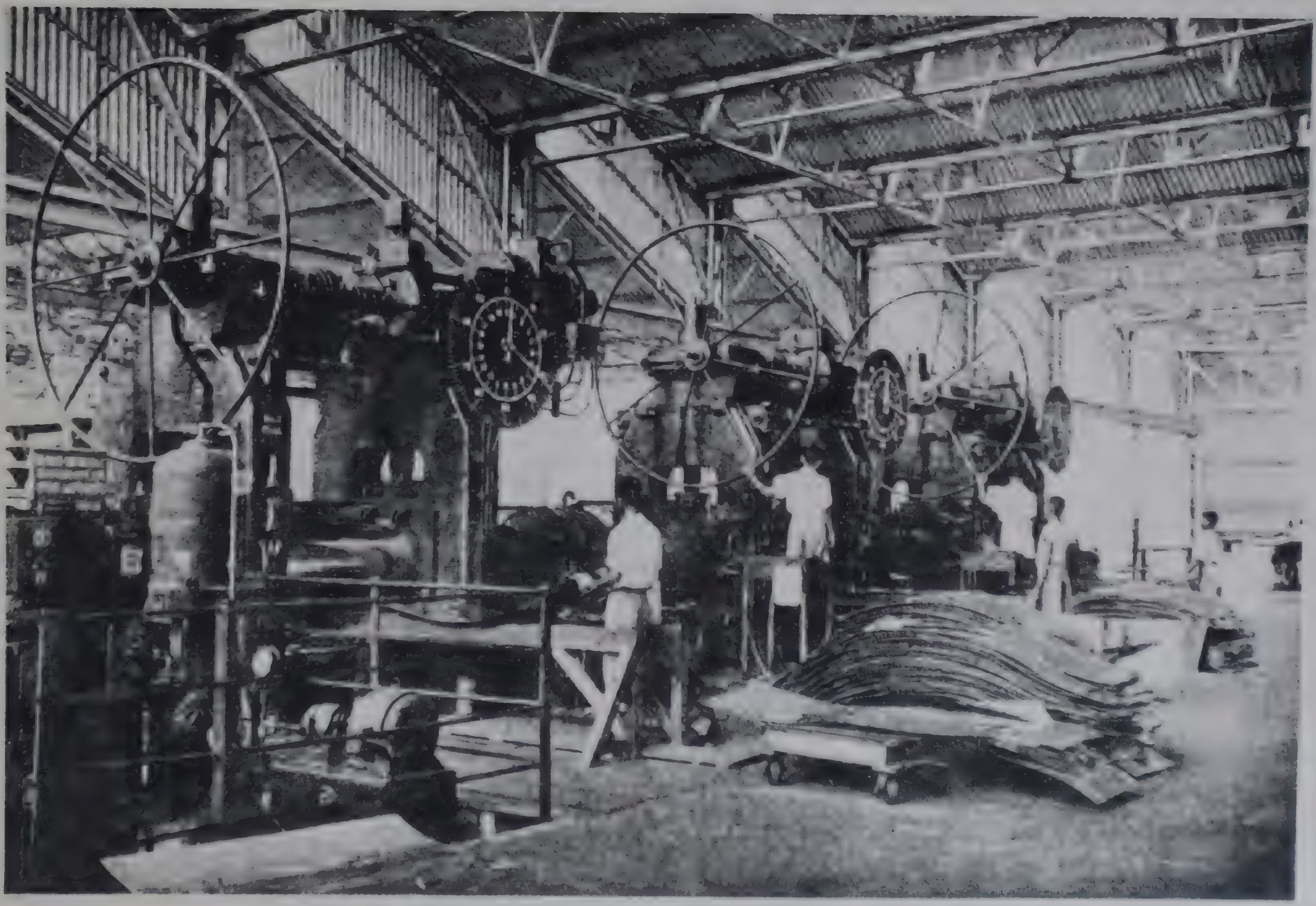
The present capacity of Indian rolling mills is estimated at 10,000 tons of ingots



1 ELECTROLYTIC REDUCTION CELLS



2. CASTING ALUMINIUM INTO INGOTS



3. ALUMINIUM ROLLING MILLS

per annum, and the cost of rolling at As. 4 per lb. of aluminium.

PRODUCTION CAPACITY OF ALUMINIUM ROLLING MILLS
(Tons)

	Nature of products	Capacity	Present output	Capacity for expansion
I.A.C. ..	Sheets & circles, later strips and coils	1,600	1,600	2,500
A.C.I. ..	,, ,,	1,600	600	
Venesta Ltd.	Foil	700	..	..
Aluminium Industries Ltd.	Cable	1,500	..	..

AVERAGE ANNUAL IMPORTS OF ALUMINIUM AND ALUMINIUM PRODUCTS INTO INDIA
(IN CWT.)

In quinquennium ending	Ingots, blocks, bars, etc.	Circles	Sheet	Other manufactures	Total	Total val. (Lakhs of Rs.)
,, '33-34	452	71,581	2,096	6,439	80,566	65.50
,, '38-39	92	47,202	2,907	10,582	60,783	45.16
,, '43-44	593	4,701	2,627	4,961	12,882	14.64
In '44-45	18,793	2,172	5,999	305	27,215	24.20
,, '45-46	61,569	27,991	16,401	3,592	109,553	90.22

The consumption of aluminium in India hitherto has been small compared with that of other countries producing the metal. Until 1943, the entire requirements of the country were met by imports. Imports before the War ('39-45) consisted mostly of circles and sheets for the manufacture of utensils, and small amounts of cables and foil. During the quinquennium ending '38-39, the average annual imports amounted to about 3,000 tons, valued at Rs. 45 lakhs. The U. K., Germany, and Japan supplied 36, 24, and 21 per cent. respectively, of the total imports. At present, the quantities allowed to be imported are controlled and are fixed in relation to the total requirements of the country and internal production.

According to the Tariff Board, the annual consumption of aluminium in India in coming years is estimated at 20,000 tons, distributed thus : utensils, 15,000 tons ; powder, 500 tons ; foil, 700 tons ; castings, 800 tons ; engineering, 2,000 tons ; rods for steel core cables, 1,000 tons (*vide* also Non-ferrous Metal Industr. Panel Rep., 1947, 27 & 50).

Thus the metal will continue to be used mainly for the manufacture of utensils, because of India's deficiency in copper and its alloys. In the U. S. A., the proportion of aluminium used for preparing utensils to the total consumption of the metal is estimated to have decreased from 16 per cent. in the pre-war period to 10 per cent. in the post-war years, while the transport industry remains the largest consumer (33-34 per cent.). In India also, increasing industrialization and power development are likely to increase the demand for aluminium.

The sale of aluminium to manufacturers has been controlled by the Government since Mar. '45. The metal produced in India is pooled with the imported metal, and released to civil consumers at a fixed price, based on the average value of the pooled metal. The present prices ('47) per ton are : ingots, Rs. 1,600 ; and sheets and circles, Rs. 2,450.

The cost of production of aluminium in India is at present high. The Tariff Board estimated that the fair selling price of aluminium ingots per ton was about Rs. 2,400 in '46-47. With larger production, this is likely to decrease to about Rs. 2,200 in '47-48 and to Rs. 1,900 in '48-49. On the basis of the selling price already mentioned, they have suggested imposition of a specific duty of Rs. 590 per ton on imports, and a subsidy to Indian aluminium companies, to cover the difference between their fair selling prices and the rates at which aluminium is allowed to be sold.

The Government regard the production of aluminium as a key industry and are appointing a technical committee to report on the production and sale of the metal in India (*Indian Tr. Bull.*, 1947, **3**, viii, 3).

ALUMINIUM SALTS

ALUMS

Alums are represented by the general formula R'_2SO_4, $R_2'''(SO_4)_3$. $24H_2O$, where R′ and R‴ are respectively monovalent and trivalent positive radicals. They are usually the double salts of ammonium, potassium or sodium sulphate with aluminium, chromium or iron sulphate, and are readily prepared by concentrating and cooling a solution containing molecular proportions of the component sulphates. Potash alum is the common alum. Ammonia alum, chrome alum, ferric alum and soda alum find occasional uses.

Potash alum, K_2SO_4. $Al_2\ (SO_4)_3$. $24H_2O$, also known as alum alumen, forms large colourless cubes or octahedra, readily soluble in water (12 g. at 20°, and 94.4 g. at 70° in 100 g. of water), but insoluble in alcohol. The solutions are strongly acidic in reaction and have a sweetish astringent taste. Alum crystals are efflorescent. On gradual heating, they dissolve in their water of crystallization and become anhydrous at about 200°. When heated rapidly to drive off all the water of crystallization, a porous bulky friable mass is formed which crumbles into a powder known as ‘ burnt alum’. Burnt alum dissolves slowly in water and is not always completely soluble owing to partial decomposition of aluminium sulphate.

Solutions of alums coagulate proteins and precipitate them ; they harden gelatine. They also precipitate colloids.

In industry, alum is used for the same purposes as aluminium sulphate, and is largely replaced by the latter which is cheaper. It is still used as a mordant for sensitive colours, and for sizing paper of superior quality. Alum is also used in manufacture of matches to impregnate the untipped ends to render them fire-proof. Burnt alum is used by taxidermists as a preservative.

In medicine, it is used as an astringent and as a gargle, and externally as a styptic. Exsiccated alum is used as a dressing for ulcers and sores and as an astringent for swollen gums.

In north-western India, freshly burnt alum is added to the drinking water of camels and buffaloes. During the War about 300 tons per annum were used in the production of foam type fire extinguisher refills.

Potash alum is prepared from its naturally occurring minerals such as alunite and kalinite, but in India these do not occur in appreciable quantities. Alum was formerly prepared from alum shales by roasting them in air and leaching it out with water (*vide* Alum and aluminous sulphates). Alum is now produced in India by crystallizing together equivalent proportion of potassium sulphate and aluminium sulphate. The solution is concentrated and the crystals that separate out are melted to yield lump alum, or recrystallized to obtain large crystals.

AVERAGE ANNUAL PRODUCTION AND IMPORTS OF ALUM

	Production (tons)	Imports	
		Tons	Lakhs of Rs.
In quinquennium			
ending '33-34	n.a.	1,319	1.73
,, '38-39	2,781 ('37-38) 1,725 ('38-39)	311	0.48
,, '43-44	1,187	392	1.84
In '44-45	1,264	829	2.02
,, '45-46	n.a.	159	0.43

Imports during the quinquennium ending '38-39 were chiefly from the U. K. (66 per cent.) and Germany (26 per cent.).

Ammonia alum, $(NH_4)_2SO_4.\ Al_2\ (SO_4)_3.\ 24H_2O$, forms colourless crystals with a strong astringent taste. In medicine, it is employed for the same purposes as potash alum. It is also an ingredient of baking powders. Soda alum, $Na_2SO_4\ Al_2(SO_4)_3.\ 24H_2O$, an efflorescent crystalline salt, is used as a mordant, in water purification, and in baking powders.

Other Alums : Chrome alum, $K_2SO_4.\ Cr_2.\ (SO_4)_3.\ 24H_2O$, is prepared by passing a current of sulphur dioxide through a solution of potassium dichromate until there is no further change of colour. On concentrating the solution and cooling it, chrome alum separates out in dark violet-red crystals. It is used in the chrome tanning of leather, and as a mordant in the textile industry. For these purposes, it is being displaced by dichromates. Ferric alum, $(NH_4)_2SO_4.\ Fe_2\ (SO_4)_3.\ 24H_2O$, forms violet crystals. It is used in medicine as an astringent gargle and as a paint for the throat, and internally to arrest haemorrhage. It is also employed in the textile industry as a mordant.

ALUMINIUM SULPHATE

Aluminium sulphate forms white crystals (*d*, 1.62) of the formula $Al_2(SO_4)_3.\ 18H_2O$, readily soluble in water (87 g. in 100 g. at 0°, and 128 g. at 30°), but insoluble in alcohol. Owing to hydrolysis its solutions are acidic in reaction. The anhydrous salt is obtained by dehydrating the crystals at 200-250°, and this decomposes completely at 750° yielding alumina, sulphur dioxide and sulphur trioxide. Aluminium sulphate solutions are similar in properties to alum solutions, but they are somewhat more astringent.

The largest use of aluminium sulphate is in water purification. Its clarifying action is due to aluminium hydroxide formed by hydrolysis. This carries down colloidal impurities, and forms a slimy layer at the bottom. Aluminium sulphate is used in sizing paper, in tanning, and as a waterproofing and fireproofing agent. In the textile industry, it is used as a mordant and for the preparation of lakes. It is also extensively employed in several industries as a clarifying agent.

In medicine aluminium sulphate is used as an astringent and antiseptic.

Aluminium sulphate is marketed in various grades. The cheapest grade called 'alum cake' is prepared by treating purer varieties of calcined china clay with sulphuric acid, and allowing the reaction mixture to solidify. It contains 13 per cent. of Al_2O_3 and all the silica and other impurities originally present in clay; insoluble matter in it may be up to 27 per cent. The two principal varieties now marketed are 'aluminoferric' and 'aluminous sulphate.' The former is prepared from low-iron bauxite. After treatment with sulphuric acid and allowing the solid residue to settle, the clear liquor is run out, concentrated by boiling, and allowed to solidify. Aluminoferric usually contains 14-15 per cent. Al_2O_3. It is consumed in very large quantities for the purification of drinking water, and in the treatment of sewage, where the presence of iron sulphate does not matter. It is prepared at site in some of the larger waterworks, and the solution employed directly for clarification. Sometimes barium sulphide or some other reducing agent is added during boiling. This reduces the iron content to as low a figure as 0.1 per cent. and improves the colour by converting ferric iron to ferrous state. The purer quality 'aluminous sulphate' is employed for sizing paper.

Pure aluminium sulphate is prepared from aluminium hydroxide and sulphuric acid, and contains 17-18 per cent. Al_2O_3 and only traces of Fe_2O_3 (0.003 per cent.). This material is mostly employed in the textile industry as a mordant, and in calico printing, and for the preparation of alums.

The present Indian requirements of alum and aluminium sulphates are estimated at 20,000-21,000 tons (for water purification, 8,500 tons; paper sizing, 10,000 tons; textiles and misc., 2,000 tons), and the five-year target for production has been placed at 38,000 tons in the Heavy Chem. and Electro-Chem. Industr. Panels Rep. (1947, 8). Most Indian sulphuric acid works produce alums and aluminium sulphates for local consumption, using good quality bauxite ore from the C. P., Central India and Bombay areas (*vide* Bauxite). Raw material requirements per ton of aluminium sulphate are 0.36 ton of bauxite, and 0.47 ton of sulphuric acid (100 per cent.). Annual production before the war was 6,000-7,000 tons, chiefly of aluminoferric, and it has now been stepped up to 16,000-17,000 tons per annum. Some factories are also preparing pure aluminium sulphate (from aluminium hydroxide), and alum.

AVERAGE ANNUAL PRODUCTION AND IMPORTS OF ALUMINIUM SULPHATE OF ALL GRADES

	Production	Imports	
	Tons	Tons	Lakhs of Rs.
In quinquennium ending '33-34..	n. a.	2,357	1.77
,, '38-39..	4,508*	1,803	1.11
,, '43-44..	8,463	1,621	1.98
In '44-45..	9,281	4,449	6.58
,, '45-46..	n. a.	1,837	3.82

* for '38-39 only.

The imported material consists mostly of the iron-free variety. During the quinquennium ending '38-39, imports were chiefly from Germany (43 per cent.) and the U. K. (34 per cent.).

Sulphuric acid is the most important single factor which influences the prices of aluminium sulphate and alums as may be seen from the prices of these compounds in India and U. K. in 1946 : --

	Sulphuric acid (*d*, 1.740) (Rs. per ton)	Potash alum (Rs. per ton)	Alumino-ferric (Rs. per ton)	Aluminium sulphate (Al_2O_3, 17-18%) (Rs. per ton)
U.K.	61/-	213/5	103/5	153/5
India*	226/-	340/-	164/-	480/- (Iron free)

*Calcutta prices (Messrs. Bengal Chem. & Pharm. Works).

The current tariff duty on imported alums is 25 per cent. *ad valorem*, or Rs. 1-6 per cwt., whichever is higher, *plus* 1/5th of the total duty. The largest consumption of alum is in Bengal.

OTHER ALUMINIUM COMPOUNDS

Aluminium oxide (*vide* Aluminium) or alumina is the starting material for the preparation of aluminium. An activated form of alumina, consisting of partially dehydrated aluminium hydroxide, has a stable highly porous structure. It is used as an adsorbent for certain gases and vapours, and as a catalyst. Fused alumina is a refractory and an abrasive. Anhydrous aluminium chloride, $AlCl_3$ is a yellowish white amorphous substance. It is now an important industrial chemical, extensively used in petroleum refining, and as a catalyst in the synthesis of several organic compounds. Synthetic cryolite, $3NaF. AlF_3$, is also used in aluminium manufacture. Sodium aluminate, $Na_2Al_2O_4$, is used in water purification, and as a mordant.

An aqueous solution of aluminium acetate, $Al(C_2H_3O_2)_3$, called 'red liquor,' is used in dyeing and calico-printing, in the preparation of lakes, and for waterproofing cloth. Aluminium stearate, $Al(C_{18}H_{35}O_2)_3$, an amorphous yellowish powder, is precipitated by the addition of sodium stearate to aluminium sulphate solution. It is also obtained by heating together aluminium acetate and sodium stearate. It is used as water-proofing agent, and is employed for thickening oils, and as an ingredient of mixed paints to prevent separation of colours. Some aluminium stearate has been produced in India during recent years, and its consumption increased during the War.

ALUMINIUM WARE

Aluminium, on account of its lightness, strength and remarkable ductility, is extensively used in the manufacture of hollow-ware, and for this purpose has to a great extent replaced brass and copper. The first aluminium ware factory in India was started in Madras in '12 by the Indian Aluminium Company. The industry received an impetus during World War I through the heavy demands for mess tins, water-bottles, etc., and several modern factories sprang up in Calcutta, Bombay and Madras.

There are at present about 50 factories in India including about 35 new factories which came into existence during World War II. Five of the larger concerns produce about 95 per cent. of the total Indian output. Of these, Messrs. Jeevanlal (1929) Ltd., Calcutta, are the biggest. This Canadian firm which has amalgamated with a former Indian concern of the same name, now owns also the Indian Aluminium Co. of Madras, and accounts for nearly 45 per cent. of all the aluminium ware manufactured in India. The other important concerns are the Aluminium Manufacturing Co. in Calcutta, the Wolverhampton Works Co., Lallubhai Amichand, and Anant Shivaji Desai, in Bombay. The first company produces about 20 per cent., and the others 10 per cent. each, of Indian manufacture (Tyson, India Arms for Victory, 1942, 140).

Aluminium for this industry is obtained in the form of circles, sheets and billets. Circles (16, 18 and 20 S. W. G. thickness) of diameter varying from a few inches up to 32" are used for most articles. Sheets are employed for containers, boxes, suitcase, etc. Wires are used for handles, and rivets for joining. Aluminium ingots and scraps are also used for the manufacture of handles, spouts, etc., by casting. Before World War II, all the aluminium sheets, circles and billets were imported. In '41, the Aluminium Corporation of India began to produce commercially pure aluminium sheets and circles from imported and indigenous virgin metal.

In pre-War yrs., the average annual consumption of aluminium was 3,000 tons, with a peak figure of 7,500 tons in '30, when the sale of utensils alone amounted to Rs. 1.5 crores. During the War ('39-45), owing to shortage of aluminium, production of utensils including those for the armed forces diminished to 25-30 per cent. of pre-War figures (Tyson, *loc. cit.*, 141). In '46, however, about 13,000 tons of aluminium were consumed in India of which 10,300 tons were imported. About 10 per cent. of the total was intended for the manufacture of articles other than utensils.

During World War II, the supply of primary aluminium was augmented by melting and refining aluminium scrap in specially installed furnaces. The price of scrap rose from As. 4 to Rs. 2-8 per lb., and Government imposed control over scrap, fixing the price at Rs. 1-12 per lb. Thereafter aluminium was released mainly for essential purposes.

Aluminium ware is manufactured by pressing, spinning or casting. In pressing, the blank after lubrication is stamped with the name of the brand and pressed into shape in power presses. Most of the presswork is usually done in one stage. Deeper pressings are done in two successive stages for lessening strain-hardening due to drawing.

The wrinkles produced are removed, and the edge trimmed and beaded during spinning. Pressing is used for the manufacture of many articles like saucepans, dishes, tea-trays, *dekchis*, tea-kettles, etc. This process is generally preferred to spinning in large-scale production, although it is costlier due to the high cost of dies, punches and presses.

In the spinning process, the blank or partially drawn article is held between a chuck and a tail piece in a lathe. A wooden or metal former, having the internal shape of the article to be produced, is attached to the chuck, and while the whole assembly rotates, the blank is forced against the chuck with the aid of tools. During spinning, the articles should be well-lubricated. The speed of rotation for aluminium spinning is about 3,000 linear ft. per minute.

Good chucks are made of hard and close-grained wood, such as babul wood, although for quality production metal chucks are preferred. Sectional or split chucks are used if the chuck cannot be removed when spinning has been completed, as in the case of *dekchis*, kettles, etc.

Spinning is adopted in the case of all re-entrant shapes ; and also for edge-curling, beading and seaming. It is cheaper than pressing. Therefore, although slower, it is preferred for small scale production even in the case of simple shapes.

Some articles are also made by hammering the sheets with mallets over wooden moulds. Smaller concerns use this process for most of their operations. Ordinary sand castings are used for making certain utensils and many parts of aluminium ware. The several parts are joined together by riveting or by welding.

Aluminium ware is finally finished by buff polishing, tool finishing, or matt finishing. In buff polishing, surface scratches are first removed with the aid of abrasive wheels and buffing is carried out in a small lathe with tripoli for imparting lustre. A spun article is directly buffed. The article is then finished with dry lime on a soft wheel. Tool finish is carried out in a lathe with edge-tools. White matt or frosted finish is imparted by chemical etching. The article is etched in boiling caustic soda solution, washed with water, and immersed in dil. nitric acid to remove black deposits formed during etching. It is finally washed with water, and dried. *Dekchis*, *thalis*, *katoras*, kettles, tiffin carriers, etc., are usually matt finished. Matt finishing may also be done by sand blasting.

Some articles are given a good brilliant finish by an electrolytic process, known as ' anodising,' followed by a colour finish. The article is made the anode in a sulphuric acid bath with lead as the cathode. This process deposits a hard film of aluminium oxide which adheres well, and resists wear and corrosion. It has also the property of absorbing certain aniline dyes giving the article an extremely brilliant appearance. The anodised article is boiled in caustic soda solution, neutralized with nitric acid, finally dyed in a vat.

Most of the factories are engaged in the production of kitchen and dairy ware. Industrial uses of aluminium ware have been developed during the last 15 years particularly by the Aluminium Manufacturing Co., Calcutta, and Wolverhampton Works Co., Bombay. Of late, industrial uses have increased greatly, and in the year ending June '42, the Aluminium Mfg. Co. manufactured Rs. 20 lakhs worth of industrial goods and only Rs. 2 lakhs worth of utensils. These articles include baskets for collecting tea leaves, latex cups and coagulating pans for rubber industry, jute mill bobbins, castings for electrical and engineering works, and equipment for paint and chemical industries. Other principal lines of production during the War were Jettison tanks, fuse pad used for gun firing, castings for distilleries, percolators for fruit juice industry, water-bottles, service utensils, auxiliary parts of electric transformers, field telephone parts, medicinal containers, etc.

The price of aluminium utensils is calculated generally on the basis of weight and depends also on the shape and the process of manufacture. Under the Aluminium Utensils Control Order (*Gaz. India*, 1945, No. 8, i, 236), the Central Govt. fixed the max. prices of domestic aluminium ware from 1st Mar. '45. The various articles were classified under 75 types for the whole of India, with 18 types more for Madras. 20 S. W. G. was specified for utensils made of circles up to 18″ in diameter ; 18 S. W. G. for those between 18″ and 24″ ; and 16 S. W. G. for those above 24″. The controlled prices range from Rs. 2-14 to Rs. 3-8 per lb.

Some quantity of aluminium hollow-ware was being exported from India to neighbouring countries. In 1937, imports from India into Ceylon amounted to 973 cwt. valued at Rs. 1,10,376 (*Ceylon Customs Returns*) ; and into Burma, 165 cwt. valued at Rs. 23,026 (*For. Tr. Burma*).

AMMONIA AND ITS SALTS

Ammonia, NH_3, is a colourless, pungent smelling gas, feebly combustible in air. It is very soluble in water (at 0°, 1148 c. c. dissolve in 1 g. of water ; at 20°, 690 c. c. ; and at 40°, 403 c.c.), and the solutions smell strongly of ammonia. The gas also dissolves in alcohol, ether and other organic solvents. Aqueous solutions are alkaline and neutralize acids forming ammonium salts.

Ammonia (t_c, 132° ; p_c, 112 atm.) is easily liquefied by compression, and liquid ammonia is a colourless mobile liquid (*d*, 0.6382 ; b. p., 33.4°). At 0°, its latent heat of evaporation is 302 g.-cal./g. Liquid ammonia is a very good solvent for numerous materials.

Anhydrous ammonia is marketed in steel cylinders, and aqueous solutions are transported in glass bottles or carboys. Liquor ammonia (sp. gr./15°, 0.882) contains 35 per cent. NH_3 by weight.

Great care should be exercised in handling ammonia and its solutions, and in opening its containers. Sudden exposure to ammonia vapours causes injuries to eyes, and suffocation, sometimes resulting in death. In case of poisoning by ammonia solutions, dil. acetic acid or lemon juice should be given, followed, if necessary, by an injection of morphine.

Ammonia finds numerous uses. It is used directly in the manufacture of sodium carbonate (*vide* Alkalis), cuprammonium silk (*vide* Rayon), and in synthetic chemical industry (dyes, drugs, plastics, nylon, urea, etc.). It is employed as a process material in textile industry, in rubber manufacture, and in the nitriding of steel. In water treatment it is used to remove the excess of chlorine. Since it readily breaks up into its elements under the influence of heated catalysts, the gas is sometimes employed as a source of hydrogen in the welding of metals.

Ammonia is also used in medicine. A dil. solution (10 per cent.) is given as a stimulant and restorative.

Ammonia forms the basis of the modern nitrogen industry, and its salts are used in immense quantities as fertilizers. It is employed also for the manufacture of nitric acid by direct oxidation (*vide* Acids).

Ammonia is obtained as a by-product during the destructive distillation of coal, for the manufacture of coke or coal gas. It is prepared synthetically from calcium cyanamide by the action of superheated steam :

$$CaCN_2 + 3H_2O \rightarrow CaCO_3 + 2NH_3$$

and by the direct combination of its elements. The former process is becoming obsolete, and the latter accounts for the major portion of the world production of fixed nitrogen.

By-product ammonia was the only source of ammonia till the successful development of the synthetic process in Germany by Haber and Bosch in '13. Since then, world production of synthetic ammonia has increased continuously, and owing to decrease in prices, the recovery of by-product ammonia is sometimes found to be uneconomical.

In India, there are at present two synthetic ammonia plants, one at Belagula in Mysore (5 tons/day), and the other at Alwaye in Travancore (40 tons/day). A third factory capable of producing 350,000 tons of ammonium sulphate per annum is being erected at Sindri in Bihar by the Government of India (Rep. Tech. Miss. Art. Fertilisers India, 1944).

The economic production of synthetic ammonia involves the preparation and purification of immense quantities of hydrogen and nitrogen, and requires a steady supply of large amounts of fuel, power, and water. After its production, ammonia has to be converted into its sulphate, or some other salt, and this again requires large quantities of raw materials (sulphuric acid or gypsum). The Travancore plant uses 3 million c.ft. of hydrogen and 1 million c.ft. of nitrogen per day, to produce 40 tons of ammonia, and consumes daily 240 tons of hardwood, 120 tons of gypsum ($CaSO_4 . 2H_2O$, 86 per cent.) and 58 tons of sulphuric acid to produce 150 tons of ammonium sulphate (*Chem. Engng.*, 1947, **54**, No. 8, 93). In the Sindri plant, the capacity of which is about 7 times that of the Travancore plant, the estimated daily requirements (300 working days in a year) of raw materials for the production of 1,167 tons of ammonium sulphate are : coal, 803 tons ; coke, 510 tons ; and gypsum, ($CaSO_4 . 2H_2O$, 93 per cent.), *ca.* 1,790 tons. A great deal of organization is necessary for the maintenance of a regular supply of these raw materials. The integration of the various processes, and the successful working of the high-pressure plant demand a high order of technical skill.

Approximately 100,000 c.ft. of a mixture of 3 vol. of hydrogen and 1 vol. of nitrogen are required for the manufacture of one ton of ammonia. Of the two gases, hydrogen is the more expensive to produce, and its cost determines the price of ammonia. Although nitrogen may be obtained from the atmosphere by the fractionation of liquid air, or by the removal of oxygen by combining it with suitable materials, in most modern plants its production is linked with that of hydrogen.

Hydrogen for ammonia synthesis is obtained chiefly by the action of steam on red-hot coke (water gas), or iron, and by the electrolysis of water. The other prominent sources are coke oven gas, (hydrogen, 50 per cent.), natural gas (chiefly methane), and by-product hydrogen from chemical industries. But these, at present, are not of much significance in India.

The credit for developing a satisfactory process for producing large quantities of hydrogen for ammonia synthesis is due to Bosch. Water gas, made by blowing steam over red-hot coke, consists of a mixture of nearly equal volumes of carbon monoxide and hydrogen. When it is mixed with producer gas (carbon monoxide and hydrogen, and nitrogen), and a large excess of steam, and is passed over a heated catalyst (iron oxide with small amounts of chromium and cerium), steam reacts with carbon monoxide and converts it to carbon dioxide, yielding at the same time some more hydrogen :

$$H_2O \text{ (steam)} + C \text{ (coke)} = CO + H_2$$
$$\text{Air (oxygen \& nitrogen)} + C\text{(coke)} = CO + N_2$$
$$CO + H_2O = CO_2 + H_2$$

The resulting gas mixture is passed through condensers to remove steam, and carbon dioxide is eliminated by scrubbing the gases under pressure (50 atm.) with water (when CO_2 dissolves readily), and then with a solution of caustic soda. Finally, unconverted carbon monoxide is removed by scrubbing the gas mixture under pressure (200 atm.) with ammoniacal copper formate. After this, only nitrogen and hydrogen are left behind with traces of inert gases (methane, argon, etc.).

Water gas and producer gas are usually mixed in the ratio 1 : 2 or 2 : 3 by volume (Curtis, Fixed Nitrogen, 1932, 223). This mixture after passing through carbon monoxide converter, and purification, contains hydrogen and nitrogen in the correct proportion for ammonia synthesis.

PERCENTAGE COMPOSITION OF WATER GAS, PRODUCER GAS & MIXED GAS

	Water gas	Producer gas	Mixed gas
Carbon dioxide ..	2-6	5	3-5
Carbon monoxide..	40-45	25	35-40
Hydrogen ..	49-51	5	33-36
Nitrogen ..	0-2	63	22-24
Argon, methane, etc.	0	2	1

This process yields hydrogen as well as nitrogen at the lowest cost, and is used for the production of the major proportion of world's synthetic ammonia output.

In the semi-water gas method, a modification of the above process, air is introduced simultaneously with steam into the gas generator containing red-hot coke, at such a rate that semi-water gas is produced. After purification this contains hydrogen and nitrogen in the correct proportion for ammonia synthesis. The Technical Mission (Rep., *loc. cit.*) has recommended the adoption of this method by the Sindri plant.

The steam-iron reaction, $3\ Fe + 4H_2O = Fe_3O_4 + 4H_2$, although it has been used for the preparation of large volumes of hydrogen for oil hydrogenation, has not found favour in the synthetic ammonia industry. This is due to the cost of production of large volumes of water gas (2.3-3 vol. for 1 vol. of hydrogen) required to regenerate iron from iron oxide. However, this is an alternative process when fuels other than coke have to be employed (cf. Rep. Tech. Miss.), and is now being used in the synthetic ammonia plant of the Travancore Fertilizers and Chemicals at Alwaye. Producer gas is generated from wood ; a part of it is used for reduction, and the rest as fuel. Nitrogen and carbon dioxide are recovered from the gases resulting from combustion.

In the electrolytic process, hydrogen is prepared by passing a direct current between nickel-plated electrodes through a 10-25 per cent. solution of caustic soda in a series of cells. But the consumption of current is very high, nearly 13,200 kw.-hr. being required for the production of one ton of ammonia. Out of this, 11,800 kw.-hr. are used for the production of 88,400 c.ft. of hydrogen (1 kw.-hr. on an average producing 7.5 c. ft., hydrogen), and 1,400 kw.-hr. for power, etc. The process is economical only in places where electricity is very cheap. A part of hydrogen produced (13,400 c.ft.) is burnt in air (32,000 c.ft.) to prepare nitrogen (25,300 c.ft. - Ernst, Fixation of Atmospheric Nitrogen, 1928, 69 and 90). A special burner is employed and the supply of hydrogen and air is so adjusted that after drying, the exit gases are made up of hydrogen and nitrogen in the correct ratio for being sent to the converters.

The Belagula plant at Mysore which uses

the electrolytic process gets its supply of current at the low rate of one eighth of an anna per kw.-hr. But even at this rate the cost of electricity per ton of ammonia synthesised works out to Rs. 103. According to Technical Mission, sufficient power is not available anywhere in India throughout the year for the production of any considerable proportion of fertilizer required. The Mission could not recommend the adoption of the process even for small plants to meet a concentrated demand in a special area.

In the original Haber-Bosch process, a purified mixture of hydrogen and nitrogen in the ratio 3 : 1 by vol. at about 500° and 200 atm. is circulated in high-pressure vessels called 'converters,' containing the catalyst maintained at 500-600°. The catalyst is said to consist of a specially prepared form of reduced iron to which are added small quantities (about 1 per cent.) of sodium or potassium oxides, alumina and silica. The formation of ammonia takes place with the evolution of considerable heat which is made use of in heat exchangers to pre-heat gases entering the reaction chamber. The gases leaving the converter contain usually 8-10 per cent. of ammonia, which is scrubbed out with water, and they are then sent back for recirculation. Haber-Bosch plants account for about one-third of the world capacity of ammonia synthesis.

The Haber-Bosch process has been modified since its introduction in numerous ways, and these changes relate mainly to the working pressure and temperature, the catalyst, and plant design. Other processes now in operation are the Casale, Claude, Fauser, Mont Cenis and the American processes.

The Claude process works at 500-650° and 900-1000 atm. With a number of converters in series, the overall yield of ammonia is about 85 per cent., and the residual gases are not recirculated. The Casale process works at 500° and at 600-750 atm., and conversion is about 15 per cent. The Mont Cenis process, on the other hand, operates at 100 atm. and 400-425° using an iron-cyanide catalyst. Its conversion efficiency is 8-20 per cent.

The Fauser and the American processes are very similar to the Haber-Bosch process. The former is characterized mainly by the use of electrolytic hydrogen produced in a special type of cells. The American processes work at 500° and 200-300 atm., using a doubly promoted iron catalyst. The plants are of special design and employ a purifier, which is really an initial ammonia converter operating at a somewhat higher temperature, in which impurities in the gases are removed by the ammonia formed. Conversion efficiency varies from 16 to 22 per cent.

The catalyst employed in the American process for synthetic ammonia production consists of iron oxide granules containing 1 per cent. potassium oxide and 3 per cent. aluminium oxide (based on the weight of iron oxide) as double promoters (*Industr. Engng. Chem.*, 1925, **17**, 971). It is adversely affected by several 'catalyst poisons', the chief of which are sulphur compounds, water vapour, carbon monoxide, carbon dioxide, and also free oxygen (methane and argon have no action). Hence the necessity for elaborate purification before the gas mixture enters the converters. The normal life of the catalyst is about 100 days. During operation its temperature is maintained at 480°, and since temperatures above 500° greatly reduce its life, the circulation of gases and heat exchange systems must be very efficient, in order to prevent overheating by any local rise in temperature.

The converter in the American system is a thick-walled cylinder of chromium-vanadium steel, and is built of a single forging, except for the head, or is a laminated structure with several concentric cylindrical forgings pressed one above the other. It contains the contact chambers made of three concentric steel tubes, the heat exchanger, and an electrically operated heating unit. This heater is required to preheat the catalyst when starting the operations, and also to supplement the heat from heat-exchangers for raising the temperature of the gas mixture to about 410° before it enters the contact chambers.

The cold gases enter from the bottom of the converter and travel up the annular space between its outer wall and the contact chambers, and keep the shell wall relatively cool. Then they pass through the heat-exchanger, and over the electrical heating coil, and enter the contact chambers, where synthesis takes place. The conversion is about 16 per cent. at a space velocity (number of litres of exit gas at N. T. P. passing over 1 litre of catalyst space per hour) of 40,000. The exit gases (510°) after passing through the heat-exchanger inside the converter are led into the condensers.

In the first condenser, which is water-cooled, the temperature of gases is brought down to 30-34°, and because of the high pressure a portion of ammonia is liquefied. In the main condenser which follows, the temperature is lowered to about 5°, by the expansion of ammonia, due to release of pressure, and all the remaining ammonia is liquefied, and sent to storage.

The unconverted gases are mixed with fresh make-up gas mixture, compressed and returned to the converter. Periodically the gases are purged to remove accumulated argon, etc. The losses due to this and to leaks, etc., in the circulation system, average to about 10 per cent.

Since the first successful operation of the Haber-Bosch process in '13, the synthetic ammonia industry made spectacular progress, and the process has become the leading method for the fixation of atmospheric nitrogen and for the production of the chemical nitrogenous fertilizers. By about '24, world production of synthetic ammonia equalled that of by-product ammonia, and in '34, outstripped the latter by about a million tons.

WORLD PRODUCTION OF CHEMICAL NITROGEN*
(1000 short tons)

	1913	1924	1929	1934
By-product ..	313	352	497	394
Synthetic ammonia ..	24	366	1,102	1,332
Cyanamide ..	42	121	251	239
Nitrate ..	473	412	555	145
Total ..	852	1,241	2,405	2,110

* Shreve, 389.

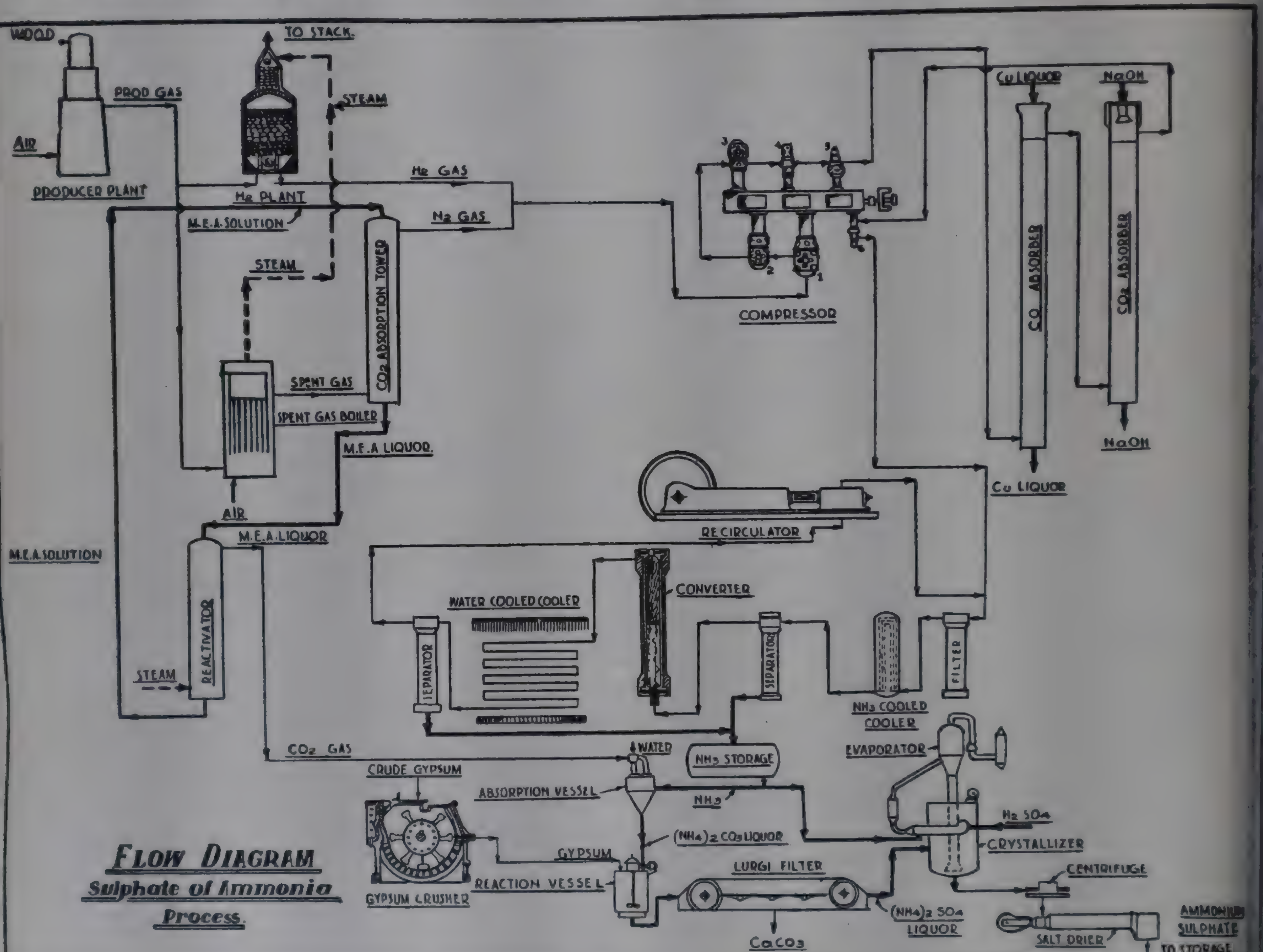
Till the commencement of the World War II, the greatest developments in the production of synthetic ammonia took place in Germany, and her annual output was far in excess of that of any other country. World capacity for nitrogen fixation about the year '40 was estimated at 4,510,000 short tons (N), and of by-product ammonia, 605,000 short tons (N). Of this, German capacity was 1,364,000 short tons (N) of synthetic ammonia, and 137,500 short tons (N) of by-product ammonia. A single titanic factory at Leuna was producing 949,000 short tons (N) of synthetic ammonia (*Industr. Engng. Chem.*, 1940, **32**, 1170).

During the last War, the largest expansion in synthetic ammonia production took place in the U. S. A. in order to meet the military demand of the allied powers for nitric acid and ammonium nitrate. In '45, the total capacity of the plants in the U. S. A. was 1,450,000 short tons (750,000 tons in Government plants, and 700,000 tons in private plants of synthetic nitrogen (*Chem. Engng. News*, 1945, **32**, 809). In England, production of synthetic ammonia and by-product ammonia in '39 was 168,000 long tons and 12,250 long tons respectively, and for '45, the corresponding figures were 201,050 and

16,875 long tons (*Chem. Tr. J.*, 1947, **120,** 191). The other countries which expanded production were Canada and the U. S. S. R.

At the same time, the capacity of Axis countries decreased considerably as a result of systematic bombing, and disruption after their defeat. Today, as a result of increased world demand for chemical nitrogenous fertilizers, there is an acute shortage, and distribution of these fertilizers is being controlled by the International Food Council. In India, distribution is carried out by the Government with a high priority for food crops.

India, however, occupies a very insignificant position in the nitrogen map of the world. Her consumption of ammonium sulphate as fertilizer rose up to about 100,000 tons in '38-39, of which nearly 75,000 tons were imported, while indigenous production of by-product ammonium sulphate from coke oven gases was only 25,000 tons. The first synthetic ammonia plant, in Mysore, started production in '41. Very recently (1947), a second plant, in Travancore, has gone into production. These two have been designed by American chemical engineers, and are expected to meet the fertilizer demands of surrounding areas.



FLOW DIAGRAM
Sulphate of Ammonia Process.

WOOD
TO STACK.
PROD GAS
STEAM
AIR
PRODUCER PLANT
H_2 PLANT
H_2 GAS
M.E.A. SOLUTION
N_2 GAS
STEAM
CO_2 ABSORPTION TOWER
SPENT GAS
SPENT GAS BOILER
M.E.A LIQUOR.
AIR
M.E.A. LIQUOR
M.E.A. SOLUTION
REACTIVATOR
STEAM
COMPRESSOR
Cu LIQUOR
NaOH
CO ABSORBER
CO_2 ABSORBER
NaOH
Cu LIQUOR
RECIRCULATOR
CONVERTER
WATER COOLED COOLER
SEPARATOR
SEPARATOR
FILTER
NH_3 COOLED COOLER
CO_2 GAS
WATER
NH_3 STORAGE
EVAPORATOR
CRUDE GYPSUM
ABSORPTION VESSEL
NH_3
H_2SO_4
$(NH_4)_2CO_3$ LIQUOR
CRYSTALLIZER
GYPSUM
LURGI FILTER
CENTRIFUGE
REACTION VESSEL
GYPSUM CRUSHER
$(NH_4)_2SO_4$ LIQUOR
AMMONI
SULPHATE
$CaCO_3$
SALT DRIER
TO STORAGE

(*Courtesy of Messrs. Fertilizers & Chemicals, Travancore*)

SYNTHETIC AMMONIA PRODUCTION IN INDIA

	Authorized capital	Rated daily output of ammonium sulphate	Construction
Mysore Chemicals and Fertilizers Ltd. (Belagula-Mysore)	Rs. 25 lakhs	20 tons	Chemical Construction Corporation.
Fertilizers and Chemicals Ltd. (Alwaye-Travancore)	Rs. 500 lakhs	150 tons	Intercontinent.

The immediate post-war requirements of ammonium sulphate fertilizer in India have been estimated at 350,000 tons. In order to make the country self-sufficient with respect to this commodity, the Government of India invited a technical mission from the U. K. with Mr. G. S. Gowing of the Imperial Chemical Industries as leader, to advise on its production. After considering the recommendations of the committee, Government started the erection of one large factory at Sindri near Dhanbad, in Bihar. The estimated capital expenditure of the Sindri plant is Rs. 10.53 crores, out of which Rs. 5.44 crores are for plant and equipment (gas generators and purification system, compressors, converters and other high-pressure equipment, condensers, etc.). Materials worth Rs. 4.12 crores are to be imported and the rest obtained in India.

In India, the industrial consumption of ammonia hitherto has been very small while in the U. S. A. the present consumption is estimated to reach 290,000 tons (*J. chem. Educ.*, 1945, **22,** 611). The average annual imports of ammonia into India in the quinquennium ending '38-39 (U. K., 68 per cent.) were only 125 tons valued at Rs. 2.7 lakhs, and nearly 90 per cent. of this was used for refrigeration. During the War, some ammonia was also employed for conversion into nitric acid in the Ordnance factories. The Heavy Chemicals and Electro-Chemicals Panels appointed by the Planning and Development Dep., Govt. of India (Rep., 1947, 27) have estimated that with the growth of chemical industries in the future, the annual industrial consumption of ammonia will be 8-10 thousand tons distributed thus: 1,500 tons for the preparation of ammonium chloride (4,000 tons) and ammonium carbonate (600 tons); 2-3 thousand tons for the manufacture of nitric acid; 4-5 thousand tons for soda ash plants; and 2-3 hundred tons for refrigeration. If a ten thousand ton urea plant is put into operation, this will require an additional 6-7 thousand tons of ammonia. The supply of these quantities are expected to become available from the Sindri plant.

Ammonium Acetate

Ammonium actetate, $NH_4.C_2H_3O_2$, (m.p., 89°) is a white hygroscopic crystalline material, readily soluble in water. It is prepared by neutralizing acetic acid with ammonia. In medicine it is used as a mild expectorant, diuretic and diaphoretic. It is also used in textile dyeing.

Ammonium Carbonate and Bicarbonate

Commercial ammonium carbonate consists of a mixture of ammonium bicarbonate, NH_4HCO_3, and ammonium carbamate, $NH_2.CO.ONH_4$. It occurs in crystalline translucent masses, soluble in water, and has a strong odour of ammonia and a pungent ammoniacal taste. On exposure it undergoes decomposition forming ammonium bicarbonate.

Ammonium carbonate is formed when ammonium sulphate is heated with calcium carbonate or by leading in ammonia, carbon dioxide and steam into water-cooled lead chambers. It is used in medicine as smelling salts, and is a valuable expectorant and carminative. It is also employed in the preparation of baking powders.

Ammonium bicarbonate is formed when ammonia and cabon dioxide in molecular proportions are passed into water at 40°.

It may be prepared from commercial ammonium carbonate by dissolving out carbamate by means of alcohol. It is a crystalline powder and has a faint odour of ammonia and a pungent taste. When heated (36-60°), it decomposes giving ammonia, carbon dioxide and water. It is used in baking powders.

The average annual imports of ammonium carbonates during the triennium ending '38-39 were 600 tons valued at Rs. 1.85 lakhs. The chief suppliers were the U. K. (66 per cent.) and Germany (22 per cent.).

Ammonium Chloride

HIND.—*Nausadar* ; OTHERS—*Nausagar*.

Ammonium chloride, NH_4Cl, commonly known as salammoniac, is a white crystalline solid with a fibrous structure. It is odourless and has a saline taste. It is slightly hygroscopic and is readily soluble in water. When heated, it volatilizes.

Ammonium chloride is used in galvanizing, in dyeing and calico-printing, and in the manufacture of Leclanche' cells and dry batteries. It is employed as a soldering flux, and in electroplating. In medicine, the salt is used as an expectorant, diaphoretic and diuretic, and in inhalations.

The salt is generally not used as fertilizer, as it is likely to increase the total chlorine content of the soil when other fertilizers like potassium chloride are also employed. In other cases it is as effective as the sulphate, but it is slightly more expensive. A fertilizer grade of synthetic ammonium chloride contains, N, 24 per cent.

Ammonium chloride is more effective for grain crops than for root crops. When applied to barley, the grains contain a lower percentage of nitrogen than when ammonium sulphate is used, which raises its malting and money value.

Ammonium chloride is usually produced by passing ammonia gas into hydrochloric acid, or by neutralizing ammoniacal liquor with hydrochloric acid. The salt is purified by crystallization from water, or by sublimation. A very pure product is obtained by mixing gaseous ammonia and hydrogen chloride diluted with hydrogen, maintaining the temperature at 230-310°.

In certain villages of the Punjab (Karnal dist. and Patiala State), small quantities of crude *nausadar* collect in the colder parts of brick-kilns called *pazawas* which are fired by refuse. This material is recovered and purified by crystallization or sublimation, and various grades of the product (NH_4Cl, 13-99.8 per cent.) are locally marketed (Dunnicliff, *Proc. nat. Inst. Sci., India*, 1943, **9**, 163 ; Sarin, *Sci. & Cult.*, 1941-42, **7**, 107) .

The average annual import of ammonium chloride during the triennium ending '38-39 was about 1,500 tons, valued at Rs. 3.88 lakhs. The principal suppliers were the U. K. (46 per cent.), and Germany (25.3 per cent.).

Ammonium Nitrate

Ammonium nitrate forms colourless deliquescent crystals (m. p., 153-166°), which are highly soluble in water. The salt decomposes above its m. p. (210°) yielding nitrous oxide : $NH_4.NO_3=N_2O+2H_2O$. If heated suddenly to high temperature or detonated, it explodes with great violence : $2NH_4NO_3=2N_2+4H_2O+O_2$. The molten salt also decomposes with explosion in the presence of traces of organic materials. It is packed in barrels or casks marked ' Dangerous '.

Ammonium nitrate is used in the production of munitions, and is a constituent of the high explosive amatol (a 50 : 50 or 80 : 20 mixture of ammonium nitrate and trinitrotoluene). It is also used in the preparation of nitrous oxide (' laughing gas '), in fireworks, and freezing mixtures. In recent years, it is being increasingly used as fertilizer.

In the manufacture of ammonium nitrate, nitric acid (40-50 per cent.) is added to ammonia liquor (25-30 per cent.), in closed iron tanks provided with agitating gear and cooling coils. The resulting solution is kept slightly alkaline, filtered and evaporated in vacuum pans. The crystals are separated from the mother liquor and are dried by a powerful stream of warm air.

Ammonium nitrate for the production of amatol was manufactured in India, during the War, in the high explosive factories.

Since '46-47, some ammonium nitrate (nitra prills *vide infra*) is being supplied to tea estates for use as fertilizer.

Ammonium Nitrate as Fertilizer

Ammonium nitrate is the quickest acting nitrogenous fertilizer, and when pure, it contains 35 per cent. of nitrogen, half of which is in the form of nitrate and half in the form of ammonia. It suffers from two disadvantages which have hitherto restricted its use as fertilizer : it is hygroscopic and sets to a hard mass, especially in a moist climate ; and under certain conditions it is a dangerous explosive.

In order to overcome these disadvantages, ammonium nitrate is mixed with powdered chalk and marketed under the name 'nitrochalk.' This contains about 44.3 per cent. ammonium nitrate and 51.8 per cent. calcium carbonate, with 20.5 per cent. of nitrogen. Nitrochalk can be used in all kinds of soils, since calcium carbonate present in it counteracts the tendency of ammonium nitrate to make the soil acid. 'Leuna Saltpeter' BASF, developed in Germany, is said to consist of a double salt of ammonium nitrate and ammonium sulphate, containing about 26 per cent. nitrogen, one-fourth as nitrate, and three-fourth as ammonia.

The problems connected with the direct use of ammonium nitrate as fertilizer have been tackled with a large measure of success in America, during the last few years, in order to find an outlet for the surplus production of Government factories erected during the War. The caking difficulties are overcome by graining or 'prilling'. The molten nitrate while being stirred is cooled under carefully controlled conditions, when rounded granules, composed of several fine crystals, are formed. These are subsequently screened to separate granules which pass through 12 mesh (*Indust. Engng. Chem.*, 1946, **38**, 709). In prilling, a concentrated solution of the nitrate is sprayed at the top of a 70′ tower. When going down, the droplets meet a counter-current of hot air and solidify to spherical prills, 'nitraprills' of the size of buck-shot (*Chem. Tr. J.*, 1944, **114**, 128). The granules and prills are conditioned by coating them with a water-repellent, consisting of 1 per cent. of a petroleum-rosin-paraffin mixture (1 : 3 : 1), subsequently dusted with 4 per cent. kaolin, and packed in multi-wall paper bags, with one or two moisture-proof plies. The material thus prepared possesses good storage properties and drillability.

The consumption of ammonium nitrate in the U S. A., during the fertilizer year '43-44, was approximately 300,000 tons, and American farmers have now become familiar with the use of conditioned ammonium nitrate (*J. chem. Educ.*, 1945, **22**, 611).

Ammonium nitrate, as such, is not explosive, but it explodes with great violence when mixed with certain materials, or when it is acted upon by a high velocity detonator. Investigations by the U. S. Dep. of Agric. have shown that in spite of several disastrous explosions connected with ammonium nitrate, when pure and in ordinary conditions, it is relatively safe

(*Chem. metall. Engng*., 1944, **51**, No. 4, 101; *Chem. Engng*., 1947, **54**, No. 5, 147), and the danger is further minimised when it is granulated.

The Technical Mission on artificial fertilizers opined that the best methods of conditioning ammonium nitrate then available (1944), could not be considered to yield a product comparable to the sulphate for the conditions of storage, transport and application, likely to be found in India. Besides, ammonium nitrate was new to Indian agricultural experts and they were not prepared to recommend its trial without extensive field trials spread over several seasons. However, India's lack of sulphur resources, and the difficulties of access to, and transport of, large quantities of high grade gypsum might force the country to re-explore the possibilities of the manufacture of nitrate-based fertilizers.

Ammonium Phosphates

There are three ammonium salts of phosphoric acid, the acid being tribasic. Of these, triammonium phosphate, $(NH_4)_3.PO_4$, is unstable, and on exposure to air gives off ammonia forming diammonium phosphate, $(NH_4)_2.HPO_4$. The latter and monoammonium phosphate, $NH_4.H_2PO_4$, are obtained in the form of white crystals or powders, and are readily soluble in water. A solution of monoammonium phosphate is mildly acidic, and a solution of diammonium phosphate, feebly alkaline.

Monoammonium phosphate is prepared by leading in ammonia into 75 per cent. phosphoric acid. Considerable heat is evolved and the solution becomes pasty. On cooling, it solidifies into an almost solid crystalline mass. In the preparation of the diammonium salt, phosphoric acid of 35 per cent. concentration is employed. If the acid is stronger, the rise in temperature is so great that absorption of ammonia becomes incomplete, resulting in the formation of a mixture of the two salts (Shreve, 349).

The most important use of ammonium phosphates is as fertilizer and they form a ready source of both nitrogen and phosphorus :

	Per cent.	
	NH_3	P_2O_5
Monoammonium phosphate ..	14.8	61.7
Diammonium phosphate ..	25.8	53.8

The fertilizer is marketed under the name 'Ammophos', and is usually sold in two grades :

	Per cent.	
	NH_3	P_2O_5 (available H_3PO_4)
'Ammophos A' ..	13	48
'Ammophos B' ..	20	20

Mixed fertilizers containing other plant nutrients, such as ammonium sulphate and potassium chloride, are also marketed. "Leunaphos" and "Diamondiphos" contain varying proportions of ammonium sulphate.

The technical grades of ammonium phosphates are also used for fire-proofing textiles and timber, and in the manufacture of yeast. The medicinal salt is a mixture of mono-, and diammonium phosphates and is employed as a diuretic.

Ammonium phosphate is always used in combination with other plant nutrients

1. AERIAL VIEW OF SYNTHETIC AMMONIA FACTORY

2. CONVERTER IN ERECTION

3. CONVERTER ASSEMBLY

(compound fertilizers). Before the War, Imperial Chemical Industries (India) were importing 'Nicifos 22/18' (N, 17.5 and P_2O_5, 17.5 per cent.; Rs. 8-6-6 per cwt.). At present, ammonium phosphate (N, 16 and P_2O_5, 18 per cent.) of Canadian origin is being imported by the Government, and the price is Rs. 15-8-0 per cwt.

The average annual imports of ammonium phosphates during the quinquennium ending '38-39, mainly from U. K., were 4,400 tons valued at Rs. 6.50 lakhs.

Ammonium Sulphate

Ammonium sulphate, $(NH_4)_2SO_4$, is obtained in brownish-grey to white crystals depending upon the degree of purity. The salt (sp. gr., 1.77) is odourless, and has a sharp saline taste. It is stable and melts at 140°. It is soluble in water (about 3 parts in 4), but is insoluble in alcohol.

Ammonium sulphate is extensively used as fertilizer and forms more than 50 per cent. of all the nitrogenous fertilizers produced. The salt is sometimes used as a source of ammonia. Commercial grades contain 0.4 per cent. acid and 3 per cent. moisture. The synthetic product is 99.5 per cent. pure (N, 21.1 per cent.) and its moisture content is less than 0.3 per cent. The salt is packed in bags or barrels.

Ammonia is converted into the sulphate by two processes: (*a*) by neutralization with sulphuric acid, and (*b*) by the gypsum process.

In synthetic ammonia plants neutralization is carried out in a large lead-lined 'saturator'. The acid is fed from above, and ammonia bubbled from the bottom, both at a uniform rate, maintaining the acidity at 1.5-3 per cent. The temperature is kept at 80-90° by the heat of neutralization and by bubbling steam through the solution. When the solution is saturated with ammonium sulphate, the salt begins to crystallize out, forming a slurry. This is prevented from caking by agitation. When the percentage of solids in the slurry reaches 40-45 per cent., the entire contents of the saturator are transferred to a sump tank. After settling, the clear liquid is returned to the saturator, and the crystals, centrifuged and washed with water or dil. ammonia to free them from adhering liquid. They are then dried in a rotary-kiln, screened to remove fine dust, and bagged.

The production of pure white and uniform crystals requires careful control of conditions. Crystallization is carried out in a slightly acid solution containing a trace of a tervalent ion. The formation of large crystals is induced by the addition of small amounts of phosphates or phosphoric acid (Thorpe, I, 251). The salt thus prepared does not cake when stored.

In the Fauser process, sulphuric acid is sprayed into chambers in counter-current with ammonia gas. The heat of reaction is sufficient to produce solid sulphate in granular form, and this has no tendency to cake (Thorpe, *loc. cit.*).

In the recovery of ammonia from gases formed during coal carbonization (coke oven or coal gas), tar is first separated from them, and they are then bubbled through sulphuric acid. Alternatively, the gases are stripped of their ammonia content by passing them through water, the gas regenerated from solution, and absorbed in sulphuric acid (*Trans. Min. geol. metall. Inst. India*, 1940, **35**, 381).

In the gypsum process, ammonia is first carbonated to form ammonium carbonate, and a solution of the carbonate (40 per cent.) is reacted with finely ground gypsum or anhydrite (40 mesh). In some plants, ammonia and carbon dioxide are passed directly into a reaction vessel which contains a suspension of powdered gypsum in water. After filtering off the precipitated calcium carbonate, the solution contains about 55 g. of ammonium sulphate in 100 c. c. This is then transferred to steam-heated evaporators and crystallization is carried out under partial vacuum.

Calcium carbonate obtained in the process contains traces of nitrogen, and may be used for agricultural purposes, as a dressing for land deficient in lime, or for the manufacture of cement.

In India, the synthetic ammonia plant at Belagula (Mysore) employs the neutralization process, and produces 20 tons of the sulphate per day (6,000 tons per annum). The Travancore factory at Alwaye combines the two processes, and produces 150 tons of sulphate per day (*J. sci. industr. Res.*, 1947, **6**, 13). This factory obtains its supplies of gypsum (150 tons/day) from the Trichinopoly area, estimated to contain 15.3 million tons. The ore is about 86 per cent. pure, and is crushed and washed before it is reduced to powder.

The Sindri factory is designed for the production of the sulphate by the gypsum process. The annual gypsum consumption of this factory is estimated at 536,000 tons, and the gypsum reserves are located in the Salt Range (70 million tons) in West Punjab, and in Bikaner and Jodhpur States (15.6 million tons). The mineral from the Salt Range (Khewra and Daud Khel) is of high purity (92-94 per cent.). The deposits also contain anhydrite and investigations have been undertaken to determine the reserve available. The use of anhydrite is expected to reduce the cost of production of ammonium sulphate (Rs. 119 per ton) by about Rs. 3.5 per ton, as it is free from water (gypsum contains about 20 per cent. H_2O). The Jamser deposits (8.12 million tons) in Bikaner form an alternative source, although the mineral is of poorer quality (83 per cent.).

The average annual imports of ammonium sulphate in the quinquennium ending '38-39 were 56,000 tons, valued at Rs. 57 lakhs, and the U. K. was the principal supplier (85 per cent.). The consumption in India rose up to nearly 100,000 tons in '38-39. The production of by-product ammonium sulphate from coke oven gases was about 25,000 tons per annum before the War, the yield per ton of coal coked being 25 lb.

Imports of ammonium sulphate are duty-free. Before '39, the Imperial Chemical Industries (India) were the chief importers. World supplies of ammonium sulphate are now controlled by the International Emergency Food Council, and price fixation and internal distribution are made by the Government, with a high priority for food crops, such as, paddy (60 per cent.), and wheat (15 per cent.). At present, there is an acute shortage, owing to increased world demand for food production, and India gets hardly 50 per cent. of allotments made.

In India, the retail price of ammonium sulphate was Rs. 8-2 per cwt. in '39, and Rs. 15 per cwt. in '47. The prices for the same years in the U. K. were Rs. 5-6 and Rs. 6-7 respectively. This brings into prominence the urgency for the production of this essential fertilizer in India.

Ammonium Sulphate as Fertilizer

Ammonium sulphate is probably the most extensively used inorganic nitrogenous fertilizer. In the soil, it reacts with clay and humus, forming an insoluble ammonium complex. Ammonia in the complex is then converted into nitric acid by bacterial action during 7-10 days, and the latter presumably forms calcium nitrate by reacting with calcium carbonate. Hence, ammonium sulphate tends to make the soil acidic due to removal of calcium carbonate. This defect may be overcome by giving a dressing of lime.

Ammonium sulphate is usually applied to the soil at the rate of 1-2 cwt. per acre, often with a suitable proportion of superphosphate, and in the case of some crops, also used along with potassium sulphate. It acts very well when used in combination with organic manures, which improve the texture of the soil. It is not so easily leached out as sodium nitrate, and hence it gives better results in regions of heavy rainfall.

According to Russell (A Student's Book on Soils and Manures, 1945, 159), the increase in yield per cwt. of ammonium sulphate per acre, in the presence of sufficient phosphate and potash is : wheat (grains), 280 lb.; barley, 336 lb. ; hay, 4-6 cwt. ; and potatoes, 20 cwt. The fertilizer is especially valuable for potatoes, barley and grass. In the case of potatoes, since the tendency to soil acidity does not injure the crop, the fertilizer may be used up to 4 or more cwt. per acre.

In some experiments in India, one maund of ammonium sulphate, in addition to normal light manuring, gave the following additional yields per acre : sugar cane, 55 ; potatoes, 15 ; leaf tobacco, 1.2 ; tea, 1 ; paddy, 4.5 ; wheat, 3 ; seed cotton, 1.6 maunds (Russell, Rep. Work Imp. Coun. Agric. Res. Sci. Crop Production India, 1937, 58).

In India, ammonium sulphate is used principally for paddy, wheat, sugarcane, and some of the plantation crops. The dosage varies from 1-5 md. per acre depending upon the crop, the soil and the climate (*vide* Burns, Tech. Possibilities Agric. Develop. India, 1944 ; and *Madras agric. J.*, 1944, **32**, 47 and 83). The fertilizer is generally applied either at sowing time or before transplanting seedlings. Later applications have not been beneficial except in the case of irrigated cotton in the Punjab.

A review of recent investigations on the application of fertilizers to crops in India has been included in a report by Stewart on 'Soil Fertility Investigations in India with special reference to manuring' (1947, 117-156). Extensive experiments have been carried out with ammonium sulphate. In the case of rice, the increase in yield ranges from 13-70 per cent. for dosages varying from 15-60 lb. of N per acre. The response to the addition of superphosphate is not much. According to Burns (*loc. cit.*, 53), the increase in yield per md. of ammonium sulphate varied from 1.99 md. of paddy in the Punjab to 4.42 md. in Madras, the average increase for all India being 3.44 md. (275 lb.) of grain and 7.26 md. (581 lb.) of straw. To obtain any tangible improvement, a minimum dose of 20 lb. N per acre appears to be necessary, and where the average level of fertility is high in other respects, it may be increased to 60-80 lb. N per acre in certain centres (Stewart, *loc. cit.*, 156).

In the case of wheat, the increase in yield varies with soil, climate, and agricultural conditions. In Bihar, where the soil is deficient in phosphates, a combination of ammonium sulphate with phosphate gave a better response, while in the U. P. the effect of adding phosphates was not so clear. Generally, a combination of organic and inorganic N, or a combination of N and phosphorus have a better response than any of them applied singly. According to Burns (*loc. cit.*, 60), the use of 1½-2 md. of ammonium sulphate per acre resulted in an average increase of 2½-3 md. (200-250 lb.) of grain per md. of fertilizer.

For sugarcane, nitrogenous manuring is a necessity throughout India, while phosphatic and potassic fertilizers have proved advantageous only in a few places. The optimum dosage varies from 60-225 lb. of N per acre in different parts of the country, and it is much lower in the Indo-Gangetic alluvium than in the peninsula. The best results, from the point of view of both tonnage and quality of juice, are obtained when ammonium sulphate is used in combination with organic manures.

HARVEST DATA AT SOME STATIONS*

	Average yield per acre in lb.		Per cent. of increase in yield of per acre	Sucrose content of juice (per cent.)	
	Control	With ammonium sulphate		Control	With ammonium sulphate
Lyallpur ('37-38)	58,794	77,552	32	..	..
Shahjahanpur ('37-38)	35,771	47,499	33	15.43	14.46
Muzaffarnagar ('36-37)	68,180	101,500	49	12.85	11.99

* Rege, *Imp. Coun. Agric. Res. Misc. Bull.* No. 41.

Groundnuts gave an average increase of 12 lb. of nuts per acre per one lb. of N (Stewart, *loc. cit.*, 144). Since the crop makes a large demand on soil potash, the addition of potash to ammonium sulphate gives enhanced yield. In the case of irrigated groundnuts, Nicifos I (N, 13.5; P_2O_5, 40.1%) and Nicifos II (N, 17.5; P_2O_5, 17.5%) gave striking response.

In regions of moderate rainfall (about 38.6 inches), the increase in yield of cotton per acre, when 125 lb. of ammonium sulphate were applied, was about 60 lb. in poor soils, and 96 lb. in fertile soils. The effect of fertilizers on potatoes is most marked, and it is quite possible that production on existing acreage can be at least doubled (Burns, *loc. cit.*). Tobacco is another crop to which ammonium sulphate is very beneficial. Among garden crops, chillies and cabbage respond satisfactorily to this fertilizer (*vide* Rep. Tariff Bd. Heavy Chem. Industry, 1929, 122-124).

In general, there is a universal response of crops to nitrogen, a conditional response to phosphate and a general absence of response to potash. In the case of certain crops, a phosphate supplement to nitrogen in particular areas has given striking increases in yield.

AVERAGE ANNUAL IMPORTS OF AMMONIA AND ITS COMPOUNDS

(Qty. and val. in thousands)

In quinquennium ending :	Ammonia		Ammonium carbonate		Ammonium chloride		Others (nitrate, acetate, etc.)		Ammonium compounds used as fertilizers			
									Ammonium sulphate		Ammonium phosphate	
	Cwt.	Rs.	Cwt.	Rs.	Cwt.	Rs.	Cwt.	Rs.	Tons	Rs.	Tons	Rs.
„ '33-34	2.5	261.1	n.a.	n.a.	n.a.	n.a.	..	..	25.7	2,983.7	n.a.	n.a.
„ '38-39	2.5	273.4	11.1*	185.6*	23.1	388.2*	3.6*	69.3*	55.7	5,663.3	4.4	650.9
„ '43-44	2.1	218.3	9.5	322.5	30.7	704.1	4.3	242.7	23.5	3,240.4	0.52	112.4
In '44-45	3.3	467.9	26.8	1,009.8	107.5	2,472.4	13.6	573.5	50.8	10,860.8	10.2	2,714.0
„ '45-46	3.1	393.9	8.3	279.1	27.4	851.0	17.7	355.5	69.3	14,374.3	3.9	968.5

* Figures correspond to triennium ending Mar. '39.

The customs duty on ammonia is 30% *ad valorem*; and on ammonium carbonate, ammonium chloride etc., it is 36% *ad valorem*; the preference rate for materials from the U. K. being 24%. Imports of ammonium salts used as fertilizers are duty free.

ANTIMONY

Antimony (sp. gr., 6.72-6.86; H., 3.0-3.5; m. p., 630°) is a lustrous white metal with a bluish tinge and it is extremely brittle. It expands on solidification and this property is also shown by its alloys, to which, in addition, it imparts hardness.

The pure metal finds very little application. Antimony black, the precipitated metal, is used for bronzing metals and for giving the appearance of polished steel to pottery-ware. The largest use of the metal, however, is in the preparation of certain extremely valuable alloys. Type metals are essentially alloys of lead, antimony (2-23 per cent.), and tin. The addition of antimony hardens the alloy and the slight expansion on solidification gives rise to perfect impressions. White metals (bearing metals) contain varying proportions of antimony (6-19 per cent.), tin, lead and copper. Hard antimonial lead, a by-product of lead smelting works, has a higher melting point than pure lead. It is employed in the making of bullets, shrapnel, etc. Indian ordnance factories are reported to consume about 70 tons of antimony per annum (Thomas, Rep. Metall. Engng. Industr., 1944, 29). Low grade antimonial lead (Sb, 4-12 per cent.) is extensively used in the manufacture of storage battery plates. Antimony-lead alloys find numerous applications: in the preparation of collapsible tubes, lead foil, lead pipes, traps, etc. Lead containing 1 per cent. antimony is used for cable coverings. Britannia metal, an alloy of tin, antimony and copper, is used for making cheap tableware. It is noteworthy that antimony used in most of these alloys is not lost, but is recovered and used again. The consumption of antimony in the U. K. in 1946 was 5,600 tons, while that of zinc was 216,000 tons, and of lead, 193,500 tons (*Chem. Tr. J.*, 1947, **120**, 172).

Antimony white (Sb_2O_3), obtained during the roasting of antimony ores, is used as a white pigment, and as an ingredient of enamels. The trisulphide, when freshly precipitated, is orange-red, but on being heated to 200° it turns black. The black sulphide as well as the antimony sulphide liquated from the ore are used in match manufacture and in fire-works. Native antimony sulphide, after purification, is used in veterinary practice as a parasiticide (Martindale, The Extra Pharmacopoeia, I, 1941, 195). The golden antimony sulphide, which has a higher proportion of sulphur, is used as a rubber pigment. Antimony sulphide is also used in the charge of some shells for range finding, as it produces a dense white smoke on explosion. Tartar emetic (potassium antimonyl tartrate) is used in medicine and as a mordant. Some organic compounds containing antimony, such as urea stibamine of Brahmachari, are effective in the treatment of kala-azar.

The Tariff Board (Rep. Antimony Industry, 1946) places the demand in the near future at about 300 tons per annum, distributed thus: type-metals, 40; anti-friction bearing metal, 25; storage batteries, 15; munitions, 5; miscellaneous (drugs, chemicals, fire-resistant paints, solders, electrical cables, toys, etc.), 10; safety matches (crude antimony), 5 per cent.

Some antimony metal (2.75 tons) is reported to have been produced in Mysore during the years '17-19 (Rama Rao, *Quart. J. geol. Soc. India*, 1942, **14**, 173). Before the last War, Napier Paint Works used to produce small quantities of antimony at Calcutta from ores of Burmese origin, and during the War, the Star Metal Refinery, Bombay, set up a smelter at Vikhroli for exploiting the antimony deposits found at Shagor in Chitral State.

The Chitral ore contains 30-40 per cent. of antimony and traces of lead and copper, but no arsenic. It is crushed to the size of walnuts and concentrated by liquation at 550-650° when antimony sulphide melts and separates from the gangue. The liquated antimony crude usually contains Sb, 71 per cent. For conversion into the metal, it is mixed with mild steel scrap borings and soda ash and heated in a reverberatory furnace when iron combines with sulphur and liberates antimony. The 'single' metal thus obtained consists of about 92 per cent. of antimony with a small amount of iron. The liquating residues contain 12-20 per cent. of antimony. On roasting, most of it is recovered in the form of the volatile oxide, Sb_2O_3. This, when mixed with coke and roasted at about 400° in a reverberatory furnace, is reduced to the 'single' metal. The latter is refined by treating it, in the molten state, with calculated quantities of antimony 'crude'. The refined metal is 99 per cent. pure.

Trade custom demands that antimony ingots should show a fern-like structure on the surface. This effect is achieved by pouring the metal into moulds which contain a special slag mixture with a melting point lower than that of the metal. During cooling, it allows the formation of crystals on the surface of the ingots, from which it is later chipped off (Schwarz, Antimony Smelting, 1945).

The Star Metal Refinery commenced operations in '41 and their production in tons was 56 in '41, 156 in '42, 130 in '43, 105 in '44, and 157 in '45.

The cost of Chitral ore at the works in Bombay was Rs. 510 per ton in '46. Of this, Rs. 300 was merely the cost of transporting the ore from the mine to the rail-head at Durgai. The firm is planning to mechanise mining operations and to reduce the bulk of the ore by installing a flotation plant to concentrate the ore to 71 per cent. prior to transporting it. When these improvements materialise (after '48), the cost of the ore per cwt. of antimony (about 5 cwt. of Chitral ore) is expected to come down from Rs. 122.5 (1946) to Rs. 48.0 (Rep. Indian Tariff Bd., *loc. cit.*).

Before the War, the price of Chinese antimony in India was about Rs. 42 per cwt. as against Rs. 70-75 per cwt. of English antimony between '35 and '38. The war time landed cost of the latter ranged from Rs. 100-115 per cwt., and imports during this period were 200 tons in '43, 150 tons in '44, and 125 tons in '46.

The cost of production per cwt. of antimony in India, including a profit of 10 per cent., was Rs. 223.50 in '42-43; Rs. 301.25 in '43-44; and Rs. 289.00 in '44-45; and the fair selling price in 1946 was estimated to be Rs. 215 per cwt. Thus, there is at present a great disparity in the prices of locally produced antimony and imported antimony. In order to safeguard the interests of both the producers and the consumers, the Tariff Board has recommended the fixing of the selling price of antimony at Rs. 150 per cwt. and a specific duty of Rs. 60 per cwt. on imports, and a subsidy of Rs. 40 per cwt. for the indigenous product up to the end of '48, when the Star Metal Refinery is expected to be able to produce antimony at about Rs. 90 per cwt.

ARMS, ARMAMENTS AND AMMUNITION

There were six Ordnance factories in India, before World War II: the Metal and Steel Factory and the Rifle Factory at Ishapore, the Gun and Shell Factory at Cossipore, the Gun Carriage Factory at Jubbulpore, the Cordite Factory at Aruvankadu (Nilgiris), and the Ammunition Factory at Kirki. Of these, the Metal and

Steel Factory was mainly engaged in the production of alloy steels and other metals for various arms and ammunition components, and in the manufacture of artillery cartridge cases. The Rifle Factory was producing rifles and their components, bayonets and machine gun components, and carrying out repair of machine guns, while the Gun and Shell Factory was producing guns, howitzers and their components. The latter factory was also making shell, fuses, primers and miscellaneous stores. The Gun Carriage Factory was manufacturing artillery carriages and vehicles, general service wagons, transport carts and various miscellaneous articles. The manufacture or handling of explosives for ammunition was restricted to the Ammunition Factory, and the Cordite Factory. Arms and ammunition for civil purposes used to be entirely imported.

The Indian arms and ammunition industry was considerably reorganized and greatly expanded under five production-drive plans : the Chatfield plan, Post-Chatfield plan, Eastern Group plan, Transplantation plan and the Ordnance factory expansion plan. The first plan, involving a capital expenditure of Rs. 7 crores borne by the British Government, was devoted to the expansion and modernisation of existing Ordnance factories. This led to an expansion in output by about 25 per cent., and the manufacture of a wider range of arms and ammunition. The establishment of the High Explosives Factory at Kirki and the Toluene Recovery Plant at Jamshedpur were also new developments under this plan. The second plan was aimed at doubling the production of small arms and small arms ammunition, by expansion of the Cordite Factory, the Metal and Steel Factory and the Ammunition Factory. Under the Eastern Group plan, which resulted from the deliberations of the Eastern Group Supply Conference, and the Roger Mission, 21 new projects estimated to cost Rs. 16 crores were sanctioned. These included manufacture of alloy steels for guns and small arms, of gun forgings, bayonets, light machine guns, gun carriages, shell fuses, artillery cartridge cases, fuses for primers, and high explosives. Of these, 19 were Ordnance factory projects, involving the erection of 8 new factories, the reconditioning of one factory, as well as the expansion of Ordnance factories, and conversion of two railway workshops for armament production. The Transplantation plan involved the removal of factories planned in Bengal under the previous plans to safer places, the construction of five new Ordnance factories, and the expansion of two of the factories under the Eastern Group plan. The last plan envisaged the completion of 13 new projects, including those for the maintenance of imported artillery equipment and aircraft instruments, and the production of packages and respirators. The new Ordnance factories were located at Muradnagar, Katni, Ambarnath, Khamaria, Lucknow, Amritsar and Hyderabad (Deccan). The Bren Gun Factory at Hyderabad and the factories at Lucknow and Amritsar have recently closed down as Ordnance factories, while that at Khamaria is being maintained.

Besides Ordnance factories, three railway workshops were switched over to armament production, and they produced 4.5-inch howitzer and 25-pdr. shell forgings. Various civil workshops including those of the jute mill industry were also engaged in the manufacture of ammunition parts. At the peak period of the War, the Director-General of Munitions Production was utilising about 1,500 engineering workshops for the production of ammunition components.

The most important raw material for the manufacture of guns, rifles and machine guns is alloy steel. Previously, only the Ishapore Metal and Steel Factory was producing alloy steel to different specifications for shell forgings, cartridge cases, etc. During the War, the Tatas developed new alloys, such as, steel bars for production of 18-pdr. and 25-pdr. armour piercing shells, high carbon steel for high explosive shell, for guns of various calibre, chrome-molybdenum alloy steel bars for manufacture of shot, special deep drawing quality steel for cartridge cases, steel bars for manufacture of hammers for fuses, high sulphur steel bars for manufacture of nose containers for high explosive aircraft bombs, etc.

Prior to World War I, imported walnut (*Juglans regia*) was used for rifle work. Although Kashmir walnut is lighter in weight and somewhat weaker than European and American walnut, it has now been accepted as approved timber for rifle work. It can be worked to a fine finish on high speed cutting and drilling machines, and is very steady. Also seasoned timber is not liable to excessive shrinking, swelling, warping or splitting (Trotter, 1944, 222). On account of the shortage of supply from Kashmir, walnut from other areas was also accepted. Himalayan maple (*Acer pictum*) and bird cherry (*Prunus padus*) were also used for rifle work. Two more timbers, *bola* (*Morus laevigata*) and *amoora* (*Amoora wallichii*) were recommended as substitutes during the War (*Indian For. Leafl.* No. 50, 1943).

During World War II, the manufacture of armoured vehicles was undertaken at the E. I. Ry. Workshops, Tatanagar, Bengal Assam Ry. Workshops, Kanchrapara, Indian Standard Wagon Co., Burnpore and the Port Commissioners' Workshops, Calcutta. In addition, some 150-200 firms were engaged in the manufacture of various components, such as, pannier components, rifle brackets and clips, machine gun brackets and clips, water tanks, hot food containers, equipment lockers and ammunition boxes.

Chassis and bullet-proof steel were required to build armoured vehicles. The former were imported from Canada. In the initial stages, the latter also had to be imported, but subsequently Tatas developed the production of various alloy steels. These included bullet-proof armour plates varying in thickness from 14-40 mm., for the fabrication of armoured fighting vehicles, bullet-proof rivet bars for rivets, bullet-proof plate for howitzer shields and gun turrets, proof plates up to 80 mm. thickness of special alloy steel, for testing armour piercing shot, composite plates to withstand the attack of 2-pdr. shot, special austenitic steel for welding electrodes, nickel steel plates for gun carriage mountings, and special quality steel for rifle and machine-gun magazines.

Three classes of armoured vehicles were manufactured during the War : (*a*) the armoured carrier, a wheeled vehicle on a Ford chassis with an open type body, and about 2½ tons of armour, (*b*) the armoured car, of a somewhat heavier body, closed with a revolving turret mounted on the top, and (*c*) armoured general purpose vehicle, also a wheeled vehicle on Ford chassis, the body being rectangular, and covered with about 2½ tons of armour. The manufacture of spare parts for bodies and equipment for maintenance of vehicles was expanded. Between '41 and Aug. '45, India produced 3,514 water tankers and unarmoured vehicles, and 6,254 carriers, armoured cars, etc. (Commerce Dep., Statist. India's War Effort, 1947, 9).

The manufacture consists mainly in mounting armoured bodies on chassis. For this purpose, steel is cut into required forms and sizes and then assembled into bodies. The first vehicle to be designed and put into production was Mark I Carrier based on a standard V-8 Ford chassis fitted with a special front axle unit, radiator, and petrol tank, and the body was armoured with 6 mm. plate. Subsequently an improved type, Mark II Carrier, was manufactured with a rear engine Ford chassis, having 101-inch wheel base and four-wheel drive ; minimum thickness of the armour on its body was 14 mm.

Ammunition includes pojectiles used with rifles and similar weapons, propellants, fuses, cartridges and ignition devices for them. Before the War, the Ammunition Factory at Kirki was producing ammunition for small arms and pistols, and also filling shells, fuses and primers, and the Cordite Factory at Aruvankadu was manufacturing cordite, gun cotton and cannon cartridges. Three new shell-forging presses were installed at one Ordnance factory, and this enabled the production of finished cavity forgings for special types of high explosive shells, including 25-pdr., 3.7-inch anti-aircraft and 3.7-inch howitzers. Under the Post-Chatfield plan and the Eastern group plan, self-sufficiency was attained in the manufacture of high explosives, T. N. T. and Composition Exploding.

The main items of ammunition produced during the War were shells and mortar bombs, fuses and other components, grenades and bombs, mines, depth-charges, various types of small arms ammunition, anti-tank mines, anti-personnel mines, smoke generators, explosive shells, tail units for bombs, containers, etc. Grenades, mines, and bombs were not made in India before the War.

The manufacture of empty shell formed an important part of war work. Besides Ordnance factories, various railway workshops and others maintained a constant output of many components of projectiles. The production of 4.5-inch howitzers and 25-pdr. projectiles was established in railway workshops and orders were placed with them for no less than 437 items, normally manufactured in Ordnance factories, some of the new items being empty shell, empty grenades, fuses, mines, etc. The General Motors Ltd., Bombay, were making, on a mass production scale, shell of various calibre, and fuses for shell and mines. The Aluminium Manufacturing Co. manufactured huge quantities of cartridge containers and fuses, the latter being made of zinc base alloys by pressure die-casting. Messrs. Kumardhubi Engineering Works were the pioneers in bomb manufacture and their production started in June, '41. The monthly output at first was only a few hundred 3-inch bombs, which rose to 20,000 bombs in ten months. They were also making bombs of high calibre, such as, 250 and 500-pdr. for the air force. Railway workshops and several engineering firms were also equipped for bomb manufacture.

Propellants such as cordite, and its ingredients (gun cotton, nitroglycerine, etc.) are manufactured at Aruvankadu, and high explosives, such as, ammonium nitrate and T. N.T. at the High Explosives Factory. Filling is mainly done at the ammunition factories.

The manufacture of ammunition is a complicated operation requiring exacting workmanship and precision. Shell must be machined to high tolerances, and fuses are often extremely intricate. About 574 operations are involved in the manufacture of a complete round of 3.7-inch anti-aircraft ammunition, and 63 to produce a shell ; and to produce a cartridge, 54 operations (The Canada Year Book, 1945, 367).

Ammunition is finished with paints and lacquers before being packed in containers. Ammunition boxes are generally made of Burma teak. The timber should be sufficiently strong and not liable to shrink or expand too much with changes in atmospheric condition. During the War, due to the stoppage of supply, Indian teak was employed ; if properly seasoned, it is as good as Burma teak. Fir (*Abies pindrow*) and spruce (*Picea* spp.) are suitable for 18-pdr. and 4.5-inch howitzer ammunition boxes. These two may also be used for packing small arms ammunition, if slightly thicker planks are used. Kiln-seasoned *salai* was used for all kinds of ammunition boxes. Kiln-seasoned mango also was found suitable (*Indian For. Leafl.*, Nos. 2, 3 and 4, 1941).

Manufacture of some of the stores developed considerably . rifles, 11 times, bayonets, 20 times ; small arms ammunition, 4 times ; gun carriages, 20 times ; gun and mortar ammunition, 35 times the pre-war output. In addition to these, India produced a number of other ammunition items not produced before the War, ranging from small arms to big guns including grenades, mines, bombs, anti-aircraft and anti-tank shell and pyrotechnic stores. Among the more important items of armament stores produced were 6-pdr. gun carriages, tripods for light machine gun, anti-aircraft gun-sights, etc.

The value of munitions produced in India during '39 to Oct., '45 amounted to about Rs. 131 crores (Aggarwal, Hist. Supply Dep., 1947, 188).

AVERAGE ANNUAL IMPORTS OF ARMS INTO BRITISH INDIA

(In thousands)

	Firearms and parts thereof		Firearms (Govt. account)	Parts of fire-arms
	No.	Rs.	Rs.	Rs.
In quinquennium ending '38-39	15·7	19,83.3	14,59.9	23·9
,, '43-44	9·4	5,54.8	4,47.9	4·1
In '44-45	1·1	91·3	..	..
,, '45-46	0·7	1,05.4	..	..

PRODUCTION OF ARMS AND AMMUNITION IN INDIA*

Year	Small arms (No.)	Artillery equipment (No.)	Artillery ammunition (Rounds)	Mortar ammunition, grenades and mines (No.)	Small arms ammunition (Million rounds)	R. A. F. bombs 250 lb. G. P.
'39-40 (Sept.-Mar.)	18,772	97	183,430	—	77	—
'40-41	93,019	206	417,771	10,080	152	—
'41-42	198,831	348	1,135,283	190,552	203	—
'42-43	279,837	468	1,617,625	1,025,425	222	—
'43-44	366,543	417	1,972,423	1,389,568	204	885
'44-45	484,290	1,376	2,474,492	1,408,393	116	878
'45-46 (Apr.-Aug.)	286,650	134	927,624	662,428	6	—
Total ..	1,727,942	3,046	8,728,653	4,776,446	980	1,763

* Comm. Dep., *loc. cit.*, Tables 8 & 9.

AVERAGE ANNUAL IMPORTS OF AMMUNITION INTO BRITISH INDIA

(In thousands)

	Short gun cartridges filled		Rifle and other cartridges filled		Empty cases	
	No.	Rs.	No.	Rs.	No.	Rs.
In quinquennium ending '38—39..	11597.2	788.8	3615.4	213.4	787.4	22.4
,, '43—44..	6613.3	527.0	1026.4	61.4	507.9	17.4
In '44—45..	3393.2	344.4	154.0	17.2	..	..
,, '45—46..	10053.7	1037.7	591.0	56.1	..	..

AVERAGE ANNUAL IMPORTS OF GUN POWDER AND EXPLOSIVES INTO BRITISH INDIA

(In thousands)

	Gun powder (black)		Gun powder (smokeless)		Blasting gelatine, dynamite, gelatine dynamite, detonators, etc.
	Lb.	Rs.	Lb.	Rs.	Rs.
In quinquennium ending '38—39 ..	59.6	37.4	11.9	17.2	2733.7
,, '43—44 ..	14.4	12.9	2.1	9.5	2969.0
In '44—45 ..	18.8	21.3	3.6	9.7	2619.8
,, '45—46 ..	18.5	25.8	11.3	26.1	3327.5

In addition to the above, huge imports of arms and ammunitions were made into India under the American Lease-Lend Account.

ASBESTOS-CEMENT

Asbestos-cement products are made from a mixture of fibrised asbestos (15-20 per cent.) and cement, to which is added a small quantity of bonding material like sodium silicate. During manufacture, asbestos fibres acquire a uniform coating of fine cement particles and give strength and lightness to the finished product. Asbestos sheets are built up in specially designed rolling mills, in the form of thin layers of asbestos and cement which adhere firmly to each other. After reaching maturity, they are found to possess considerable toughness and flexibility, and do not show any stratification and lamination. In the manufacture of roofing slates, the sheets are subjected to high pressures, to remove air bubbles and excessive moisture, cut to size, and cured for several days in a steaming chamber.

The Asbestos Cement Ltd. (paid-up capital, Rs. 41.5 lakhs) are the only producers of asbestos-cement goods in India. Their factory at Kymore (C. P.), with a capacity of about 1,200 tons per month, started production in '34. Owing to increasing demands of the building industry near port towns, the company established two more factories, one at Bombay and the other at Calcutta. The latter started production after the outbreak of the last War. The combined production capacity of the three factories is 6,500 tons per month, and during the War, 75 per cent. of their output was taken up by the Government. It is expected that now their entire production will be available for civilian use. In '43, the three factories used to employ about 2,500 labourers.

The most important asbestos-cement products are: plain and corrugated sheets for roofing and partitions, rain-water pipes, drains and gutters, flue goods, etc. These are manufactured in India and are in considerable demand. Special products, such as pressure pipes, brake and clutch linings, decorative sheets, and electrical insulating materials are imported. Asbestos Cement Ltd. are also the chief importers.

Cement of Indian manufacture suitable for this industry is readily available. Indian asbestos which belongs mostly to the tremolite and actinolite species of amphibole asbestos yields fibres which are weak and brittle. Asbestos Cement Ltd. have examined several specimens mined in different parts of India and found that they cannot yield products of the quality which they manufacture (*vide* also, Mysore Geol. Dep., Pop. Studies No. 3, Krishnachar, Note possibilities mfg. asbestos-cement Mysore, 1943). The Mysore Asbestos Products Ltd. was blending Hole-Narasipur asbestos (tremolite and anthophyllite) with imported Canadian chrysotile asbestos for the manufacture of mill-boards. This Company went into liquidation in '23.

The imports of asbestos which were negligible before '33-34 have risen steadily with the development of the activities of the Asbestos Cement Ltd. who are the chief consumers of imported asbestos. Imports in '38-39 were 73,200 cwt. valued at Rs. 7 lakhs, and in '44-45, 211,000 cwt. valued at nearly Rs. 44 lakhs. Correspondingly, there has been a decline in the import of asbestos-cement goods into India. Imports which were 5,779 tons in '34-35 declined to 3,234 tons in '37-38, and to only 342 tons in '45-46.

AVERAGE ANNUAL IMPORTS OF ASBESTOS-CEMENT PRODUCTS

	Tons	Rs. (1000)
In quinquennium ending '38-39	3,464	4.25
,, '43-44	1,239	3.87
In '44-45	395	1.74
,, '45-46	342	4.03

During the quinquennium ending '38-39, supplies were principally from the U. K. (35 per cent.), Belgium (32 per cent.), and Yugoslavia (20 per cent.).

ATROPINE

Atropine $C_{17}H_{23}O_3N$, is the most important alkaloid obtainable from several species belonging to various genera in the family, *Solanaceae*. Probably it does not occur as such in plants except in traces, but is formed by the racemisation of its laevo-isomer, hyoscyamine, during the process of extraction. The chief commercial sources of hyoscyamine, and hence of atropine, are *Atropa belladonna*, *Datura strammonium* and *Hyoscyamus muticus*. The last one known also as Egyptian henbane is the richest source of hyoscyamine. *Scopolia carniolica* Jacq. also contains up to 0.6 per cent. of hyoscyamine.

ALKALOIDAL CONTENT OF SOURCES OF ATROPINE*

		Per cent.	
		Range	Av.
Atropa belladonna	Leaves & stem	0.2 —0.8	0.4
	roots	0.4 —0.6	0.4
,, *acuminata*	,,	0.13—0.78 0.29—0.80	0.45 0.47
Datura strammonium	Leaves & stem	0.2 —0.45	0.25
	seeds	†0.2	
Hyoscyamus muticus	,,	0.8 —1.30	

*Denston, A Textbook of Pharmacognosy, 1945 ;
†Trease, A Textbook of Pharmacognosy, 1945.

It is reported that the roots of Indian belladonna (*Atropa acuminata*) are now being used for the production of atropine in Kashmir. *Hyoscyamus muticus* is found growing in patches in West Punjab, Baluchistan and Western Sind, but its quality is poor. Attempts to prepare atropine from the leaves of *Datura strammonium* gave very low yields, 0.05 per cent. *Datura metel* which occurs in the N. W. F. P. can be used for the preparation of the related alkaloid, hyoscine (yield, 0.05 per cent. ; m. p. of hydrobromide, 193-194°).

In the preparation of atropine from Egyptian henbane, the drug is extracted by percolation with hot alcohol. The extract, after the removal of the solvent under reduced pressure, is poured into 1 per cent. hydrochloric acid. The acid liquor is separated from resinous matter, and is further purified by shaking with petrol. It is then neutralised with ammonia and is set aside when some more resinous matter separates out. The clear liquid is rendered alkaline with ammonia, and the precipitated alkaloids extracted with chloroform. The chloroformic solution is again shaken up with dil. acid and the acid layer basified with ammonia and re-extracted with chloroform. The solvent is then distilled over and the residue is converted into oxalate, which is recrystallized from water. This, when dissolved in water and treated with ammonia, gives hyoscyamine which can then be extracted with chloroform. To convert into atropine, hyoscyamine is dissolved in 0.8 per cent. alcoholic sodium hydroxide and allowed to stand until the mixture shows no optical activity. It is then neutralised with oxalic acid, alcohol removed, and the salt purified by recrystallization from water (Allport, Chemistry and Pharmacy of Vegetable Drugs, 1943, 36). The base is regenerated and converted into sulphate.

The sulphate is usually prepared by adding the requisite quantity of pure atropine to a solution of one part of sulphuric acid in 10 parts of absolute alcohol. The neutralised solution is covered with a layer of ether and the salt is precipitated in a pure state as ether diffuses into alcohol.

Atropine may be extracted from fresh belladonna plants. These are richest in alkaloidal content at the time of flowering, when they are cut and the sap pressed out. This contains most of the alkaloids. It is warmed to 80° when proteins and some of the other constituents are coagulated. After filtration, alkali is added to the sap and the liberated alkaloid is extracted with chloroform. Some organic colouring matter, mucilagenous material and resin, also go into solution. In order to separate them, the process is repeated. The solvent is removed from the final chloroformic extract and the residue is treated with very dilute sulphuric acid. The bases are again liberated by the addition of potash, filtered and crystallized from dilute alcohol.

In the case of the dried roots they are finely powdered, mixed with soda solution, and extracted with a suitable organic solvent. The extract is reduced in volume to about 1/5 or 1/10 and shaken up with dil. hydrochloric acid. The acid extract is precipitated by soda solution and the mixture of bases, after washing, is dried at 40-50°. The finely divided material is shaken up with ether and separated from mucilage. If necessary, it is decolorized by animal charcoal, filtered and concentrated. The material which recrystallizes consists mostly of a mixture of atropine and hyoscyamine and is completely converted into atropine in the manner already described (Ullmann, Enzyklopädie der technischen Chemie, 1943, I, 222).

Atropine is a colourless crystalline base (m. p., 118°). It is readily soluble in alcohol, acetone and chloroform, less so in ether, benzene, and hot water, and only sparingly soluble in petroleum ether. When heated rapidly, it sublimes unchanged. Aqueous solutions are distinctly alkaline to litmus and phenolphthalein and have a bitter taste. A single drop of 1 in 130,000 aqueous solution produces a marked mydriatic effect when introduced into the eye of a cat. Pure atropine is optically inactive, but the commercial product is slightly laevorotatory, owing to the presence of traces of hyoscyamine. It is one of the deadliest poisons known.

Atropine, in common with hyoscyamine and hyoscine, when treated with strong nitric acid, and the mixture evaporated to dryness on the steam bath, leaves a pale yellow residue, and gives a violet colouration with a drop of freshly prepared alcoholic potash. This is known as Vitali's test.

The sulphate, $(C_{17}H_{23}O_3N)_2 . H_2SO_4 . H_2O$, is the most important salt of atropine. It occurs in the form of colourless crystalline powder, and melts at 196°, when anhydrous. It is soluble in water (2 in 1), and in alcohol (1 in 4), and is insoluble in ether and chloroform. The hydrobromide melts at 163-164°, and the oxalate, at 198°.

Atropine and its salts exhibit a twofold physiological action. The alkaloid stimulates the central nervous system, where it acts especially on the motor area, and paralyses the terminations of the para-sympathetic nerves which supply glands, plain muscle and the heart. It controls excessive salivation, and in phthisis stops sweating. It is sometimes used to check nasal secretions due to coryza or hay fever.

Atropine in small doses (max., 1 60 grain) stimulates circulation and respiration. It gives relief in spasmodic affections involving the unstriped muscles as in asthma. Sometimes it is also used in whooping cough, and dysmenorrhea, and is added to laxative mixtures for preventing griping.

Atropine acts on the terminations of the nerves in the involuntary muscles of the eye and dilates the pupils widely. A one-in-two thousand solution is used in sight-testing, but the paralysis lasts for a week. It should never be used if there is any tendency to glaucoma. Consequently, for older people, it is always replaced by homatropine, $C_{16}H_{21}O_3N$, the tropic ester of mandelic acid, which is generally used in the form of its hydrobromide. Its action is milder than that of atropine and it is also comparatively less toxic. Homatropine does not give Vitali's test.

Externally, atropine, as *unguentum atropina* or as plaster of belladonna, is extensively used as a local anodyne in certain painful conditions.

The physiological action of atropine sulphate is identical with that of the alkaloid. The salt is generally employed in making hypodermic solutions (dosage : 1/240 to 1/60 of a grain). *Lamellae atropinae* are used in ophthalmology. Each lamella contains 1/1500 of a grain of atropine sulphate.

In larger doses, atropine is a deadly poison. The symptoms are similar to those of belladonna poisoning : dryness of mouth and throat, dilated pupils, dry skin, etc. The temperature is often raised and the patient becomes delirious. Death takes place from respiratory failure. In cases of atropine poisoning (taken by mouth), tannic acid should be administered (20 gr. in 4 oz. of water) and the stomach washed. Chloroform and ether may be helpful in controlling spasms, and caffein and artificial respiration are employed to control depression.

AUTOMOBILES

The automobile industry includes the manufacture of engines, chassis and body, and the assembly of these to form complete units. On account of the vital part which automobiles play in modern warfare, and the ease with which an automobile factory may be converted into an armament plant the industry may be considered "essential". In India, at present the industry is confined mainly to assembly work and commercial body building.

Before the War, the General Motors (G. M.) and the Ford Motor Co. had established assembly plants. In recent years three companies have been formed for the production of automobiles in India, with a joint capacity of 20,000 vehicles per annum. The Hindustan Motors Ltd., Calcutta, will shortly assemble motor cars imported in 'knocked down condition,' and expect to manufacture automobile engines by '50. This company is receiving assistance from the Nuffield Organisation (U. K.) and the Studebaker Corpn. (U. S. A.). The Premier Automobiles, Bombay, assisted by the Chrysler Corpn. (U. S. A.) is now assembling cars, and expect to manufacture motor cars in three years. The Motor House (Gujerat), Bombay, will work in collaboration with the Kaiser-Fraser Corpn. In addition to these three concerns, two more factories, one in the U. P., and the other in Madras, are likely to be established shortly.

MOTOR ASSEMBLY

The G. M. are pioneers in assembly work and they erected their plant in Bombay as early as '28. Soon after, the Ford Motor Co. established plants in Bombay, Calcutta and Madras. Prior to World War II, the total annual capacity of these two was 96,000 units (G. M., 60,000, and Ford, 36,000). Besides these, some distributors also carry out assembly work on a small scale. The chief advantages in assembling cars from components are savings in customs duty, and in freight, insurance and handling charges. The industry encourages training of technical personnel in the country.

Two different methods are used for assembly work. The G. M. and the Ford Motor Co. import their vehicles in 'completely knocked down' condition ; the chassis, frames, and bodies come dismembered and require riveting, assembling, painting, etc. Rear axles, power units, gear boxes, dynamos, and self-starters are received ready for installation. The chassis is assembled upon a slow moving conveyor belt; frames are placed on the conveyor at one end, and the chassis is gradually fitted with brakes, springs, axles, engine, gear boxes, dynamos, self-starters, wheels, etc. Radiators and cowl are then dropped on to the assembled chassis and bolted.

The main assembly line is fed by a number of conveyor lines carrying different parts, each feeding a component at the appropriate point. The workers stationed at various places in the line quickly fit the different parts to the chassis, and the assembled units come out in quick succession. If intended for commercial vehicles, these are sent direct to distributors and dealers. For cars, the assembled chassis is next fitted with the body, built in a sub-assembly line, and brought to position on over-head conveyors.

Some distributors import cars in a ' partially knocked down ' condition. The complete chassis is mounted underneath a pulley block for fitting and bolting the body, and accessories.

Amongst articles purchased locally for assembly work, the main item is tyres. The Dunlop Rubber Co., and Firestone Tyre and Rubber Co. have plants in India, and have been supplying a large proportion of commercial types of tyres required. Batteries (q. v.) are mostly imported, though some concerns manufacture them in India. Electrical copper wire was manufactured by the Indian Cable Co. during the War for army vehicles.

BODY BUILDING

Before the War, there was no commercial body building industry in India. The chassis for commercial vehicles, assembled from ' completely knocked down ' parts by the G. M. and the Ford Motor Co., used to be distributed through their dealers, who made their local arrangements, for the construction of the body. The G. M. were the first to establish the body building industry in India. In Sept. '39, they installed plant and machinery in Bombay for mass production, and by the end of the year produced 1,069 army type bodies. During the War, due to tremendous increase in army demand for vehicles, their plant was mainly engaged in army work and a number of other firms in Calcutta, Madras, Delhi, etc., also commenced operations. In '40, the G. M. and other important dealers were capable of supplying about 1,000 bodies per month. In '43, the G. M. reached the peak of nearly 3,000 bodies a month. Their total production during '43 and '44 was 26,105 and 27,956 bodies respectively. The Indian industry supplied 132,572 completed vehicles to the Defence Department from the beginning of the War, up to Feb. '44, and monthly production was maintained at 5,000-5,500 bodies (Thomas, Rep. Develop. Industr. War Supplies, 1944, 70).

The principal raw materials for body buildings, for commercial vehicles, are timber, mild steel sections, (channels, angles, flats and rounds), aluminium sheets, and hardware. Other items are canvas and hessian, leather, rexine, plywood and hard board, standard fittings and paint.

The chief requirements of timber for motor bodies are lightness, strength, freedom from wear and tear, especially around bolt and screw holes, and resistance to fungus attack at joints and bolt holes (Trotter, 1944, 215). In pre-war days, the use of deodar (*Cedrus deodara*) was restricted to Rawalpindi Arsenal. During the War it was not readily available in Bombay. A number of S. Indian woods, such as *poon* (*Calophyllum elatum*), *bijasal* (*Pterocarpus marsupium*) and *aini* (*Artocarpus hirsuta*) proved highly serviceable. In lorry bodies, timber is used for the runners or bolsters, which serve as bed for lorry bottoms, and as joists of the floor, and for planks used for flanks, etc. Timber for runners should be very strong, and sissoo (*Dalbergia sissoo*), rose-wood (*D. latifolia*), Andaman *padauk* (*Pterocarpus dalbergioides*), Burma *padauk* (*P. macrocarpus*) and *bijasal*, and to a lesser extent, teak (*Tectona grandis*), *sal* (*Shorea robusta*), *benteak* (*Lagerstroemia lanceolata*), *thingan* (*Hopea* spp.), *aini* and *dhaman* (*Grewia tiliaefolia*) are also used (*Indian For.*, 1947, **73**, 266). Flanks require reasonably light and resilient timber. A larger choice of woods is allowed, but deodar is preferred owing to its springy qualities; others used are cypress (*Cupressus torulosa*), *kail* (*Pinus excelsa*), *chir* (*P. longifolia*), teak, poon, *chaplash* (*Artocarpus chaplasha*), *aini*, *gamari* (*Gmelina arborea*), white cedar (*Dysoxylum* spp.), white *bombway* (*Terminalia procera*) and Andaman *pyinma* (*Lagerstroemia hypoleuca*). About 21 c. ft. of timber, inclusive of wastage, are used for one lorry.

In bus bodies, timber is used for cross-bars, bottoms, floor-boards, roof cross-members, roofs, side- and back-boards, windows, footsteps, luggage carrier frames, seats, partition walls, etc. The amount of timber required for one bus is about 53 c. ft., inclusive of wastage. Timber for bus bodies should be similar to that used for lorries, but teak is generally preferred. If teak is not available, *sal* or sissoo, without any knots, may be used. *Benteak* is extensively used in Madras for motor bodies. For station wagons, white cedar is used for pillars, doors and roof, the flooring being of teak. The timber, excepting for seat, partition and floor-boards, should be capable of taking a high finish. For hood frames, a fairly strong, elastic and tough wood capable of being bent is required. Mulberry (*Morus* spp.), *dhaman*, sissoo, rosewood, teak, *benteak*, *bijasal*, Andaman *padauk*, Burma *padauk*, Andaman *pyinma* are suitable (Trotter, *loc. cit.*).

Mild steel angles, bars and rounds are required for bus and lorry bodies. They are used for superstructure, reinforcing and supporting panels, luggage carriers, seats, etc. About 0.33 ton of steel is required for a bus body and 0.16 ton for a lorry body. Hardware, such as coach bolts and nuts, wood screws, machine screws, hinges, etc., is imported.

Plywood, used in the construction of bus bodies, is mostly imported. Masonite and other hard boards, also safety glass and window glass are imported. Hessian, canvas, cotton wadding and rexine are locally available, but indigenous rexine is of poor quality. Linoleum for flooring is imported. Certain bus bodies use an outer panel of aluminium sheet which is locally available. Aluminium strips, beadings, gutters, etc. are imported. Some paints manufactured in India are used for painting wooden portions and the interior.

Various standard fittings and accessories such as door handles, wind screen wipers traffic indicators, springs for seats are imported. Locally made door handles are of inferior quality.

At present only the G. M. are capable of applying mass production technique to body building. During the War, this was made possible owing to large army requirements of vehicles of particular designs. After a prototype is completed and approved, suitable jigs are constructed. Timber is cut and shaped; simultaneously, iron and steel sections are cut or forged to shape, drilled, and made ready for use. The assembly is carried out on line production system, and during the process the chassis is drilled and fitted with extensions. After the War, owing to decline in orders, the G. M. are not able to make full use of their plant.

A large variety of bodies are made, such as load bodies, for carrying goods and materials, with fixed or drop down sides, delivery vans, passenger buses, ambulance cars, station wagons, etc. Restrictions on length of body, and on load, influence body designing. The wheel-base of chassis for commercial types (3 tons) is usually of 166″, and those of delivery vans (1¼ and ¾ ton), 135″ and 113″. Passenger bus bodies usually have chassis of wheel-base of 160″, 175″ and 200″, and station wagons, of 113″ or 130″. During the War, several other types, such as troop carriers, wireless vans, water tanks, tipping wagons and cinema lorries, were built.

ENGINES, SPARE PARTS, CHASSIS PARTS, ETC.

Raw materials used in the manufacture of automobiles are the unfinished and finished products of other industries. Development of these subsidiary industries is therefore essential for an uninterrupted flow of raw materials. In the initial stage many of the components and parts will have to be imported till their manufacture in India becomes technologically and economically feasible. Even big firms do not manufacture all the parts of an automobile. They get many of them from subsidiary industries, and it is reported that out of 40 major items entering into a vehicle, Studebaker buys 35 items; Chrysler, 34 ; Packard, 32 ; Ford, 27 ; and G. M., 19 items.

The principal materials used in the manufacture of engines and other auxiliary parts are alloy steels, cast-irons and various non-ferrous alloys. The industry requires 118 different types of steel, 92 different types of castings, with strict conformity to specifications. Alloy steels are used for crankshafts, camshafts, gears, connecting rods, valves, etc. During the War, Tatas produced a large number of alloy steels, and may be expected to supply India's requirements of alloy steels for automobile manufacture. Grey cast-irons are used for cylinder blocks and head, brake drums, and parts exposed to heat and corrosion. Messrs. Jamshedpur Engineering and Machine Manufacturing Co. (Tatanagar), and Messrs. Burn & Co. (Howrah) are in a position to make these.

Aluminium alloys are used for pistons, and sometimes for cylinder blocks, gear boxes, and their covers. For covers, magnesium alloy also may be used. Zinc alloys, containing aluminium and copper, and occasionally magnesium, are used for a number of auxiliary parts made by diecasting, such as carburettors, petrol pump, door handles, etc. These are usually electroplated with nickel or chromium. Brass, plated with nickel and silver, is used for head-lamp reflectors. Smaller quantities of lesser known metals and alloys are also required. Nickel alloy, containing manganese, chromium or silicon, is used for sparking plug parts ; tungsten, for ignition coils, make-and-break contacts, etc. The only pure metal, needed in considerable quantities, is copper in the form of electric wire, sparking plug washers, petrol pipes, radiator honeycombs and gaskets.

Rubber and rubber-lined materials, such as flexible tubing for petrol pipes, etc. for which oil, petrol and heat-resisting rubber or synthetic rubber compounds are required, can be made in India.

So far, automobile engines have not been manufactured in India. The Hindustan Motors Ltd. are reported to be busy commencing the manufacture of engines and a few other motion parts of automobiles.

Besides batteries, a number of spare parts are manufactured in the country, but their quality has not reached the standard of foreign products. The main centres of production are Lahore, Rawalpindi, Calcutta and Madras. The parts made are bushing for driving shaft, kingpin, etc. bearings, various types of bolts, rear spring pins, fan blades and belts, hub-nuts, spanners, engine valves, washers, cylinder head gaskets, pistons, piston rings and pins, valve guides, cylinder liners, diaphragms, radiator hose, etc.

A new plant for the manufacture of automobile wheels, chassis, bumpers, brake drums and other cold pressings is proposed to be installed near Tatanagar (*Capital*, 1947, **118**, 701).

The following table gives the number and types of motor vehicles other than those owned by the military department, in use in British India during the year ending 31st Mar. '45 (*All India Motorist, Lahore*, June 1946, 12).

Motor cycles	8,934	
Private cars	73,530	
Motor cabs	7,815	
Other public service vehicles	16,088	(Including diesel-engined vehicles, 281)
Goods vehicles	24,839	(,, ,, 24,715)
Miscellaneous	2,887	(,, ,, 6)
Total	134,093	(,, ,, 411)

It is estimated that there are now under the Indian Union about 200,000 registered motor vehicles including 75,000 cars (*Capital*, 1948, **120**, 54). Imports have been heavy since the war. In 1947, nearly 21,000 new cars and 10,690 commercial vehicles were imported. This year's demand is estimated at 30,000 units, rising to about 45,000 in 1950. A substantial part of Indian requirements are expected to be met by Indian Assembly plants and Factories. The plants of the Hindustan Motors near Calcutta and Okha, when they came into full production, will be able to turn out nearly 23,600 cars per annum (Capital, *loc. cit.*, 783).

IMPORTS OF AUTOMOBILES AND PARTS

(Val. in lakhs of Rs.)

	Motor cars, including taxi-cabs		Motor omni-buses, motor vans and lorries		Chassis		Parts of mechanically propelled vehicles & accessories other than those of aircraft (excluding rubber tyres)
	No.	Val.	No.	Val.	No.	Val.	Val.
Annual av. in the quinquennium ending:							
„ '33-34 ..	10,622	217	2,035	26	5,303	86	86
„ '38-39 ..	13,544	254	295	8	9,802	131	83
„ '43-44 ..	3,660	81	413	10	13,471	250	184
In '44-45 ..	13	0.5	1	...	7,736	266	60
„ '45-46 ..	263	10	150	42	359	12	68

The U. K., Canada, and the U.S.A. were the main suppliers in the pre-war period. In the quinquennium ending '38-39, they supplied 46, 12, and 32%, respectively of the imports of motor cars and taxicabs. The corresponding percentages for motor omni-buses, vans, lorries and chassis were 22, 19 and 55, respectively, and for parts and accessories, 41, 10, and 41, respectively.

Imports of motor cars including taxi-cabs, motor cycles and articles other than rubber tyres and tubes adapted for use as parts and accessories thereof, are subject to a revenue duty of 45% *ad valorem*, and to a preferential duty of 30% *ad valorem*. Imports of motor omni-buses, chassis for omni-buses, motor vans and lorries are subject to a revenue duty of 30% *ad valorem*, and to a preferential duty of 21% *ad valorem*.

BAKERY

Bakeries manufacture bread and other yeast-raised products (buns, rolls, etc.), biscuits, crackers, and cakes. These are prepared from wheat flour dough and differ only in the nature and proportion of other ingredients, such as fermenting and leavening agents, sugar, fat, salt, etc.

In the dough, the protein (9.5-12.5%) is hydrated and swells up into a highly elastic rubber-like substance, gluten. This mixed with moist starch granules imparts to the dough its elasticity and gas-retaining properties.

Two varieties of wheat flour, hard and soft, are used, varying mainly in the quality and quantity of proteins. Hard flour contains comparatively tough and elastic gluten, capable of good gas-retention and high water-absorption, and yields well-shaped bread of good grain and structure. It is also utilized for making products allied to bread. Soft flour, on the other hand, contains a soft and incoherent gluten of poor gas-retention and water-absorption. It is used in the preparation of cakes, biscuits, etc. in which no fermentation takes place to mellow the gluten.

COMPOSITION OF WHEAT FLOUR

(Per cent.)

Description	Moisture	Proteins	Fat	Total carbohydrates	Fibre	Ash
English (1) patent ..	15.0	7.6	0.8	83.2	..	..
American (2) patent all purposes ..	12.0	10.8	0.9	75.9	0.3	0.4
American (2) patent flour for bread ..	12.0	11.8	1.1	74.6	0.3	0.5
American (2) patent soft flour for cakes or pastry ..	12.0	8.3	0.8	78.5	0.2	0.4
Indian flour (3), refined ..	13.3	11.0	0.9	74.1	0.3	0.4

(1) McCance and Widdowson, 28 ; (2) Jacobs, I, 629 ; (3) *Hlth. Bull.* No. 23, 1941, 27.

BREAD

In India, bread-making is not an organized industry and is scattered all over the country in small units, catering mostly to local demands. Moderately large bakeries are found in big cities. A number of tea and coffee shops also prepare bread, buns, etc. The Army in India has its own bakeries, and their production during World War II, increased considerably. Civilian consumption of loaves, buns, etc. is confined to a section of the population.

Strong or hard wheat flour is favoured for making bread and other allied products. The fat content of the flour should be low, since fat has a tendency to turn rancid. The flour enzymes, diastase and protease, also affect the quality of bread, the former by helping the fermentation of starch into sugar, and the latter by softening the dough through the breaking down of gluten into simpler substances. Excess of these in the flour will yield a sticky dough of low gas-retention. Insufficient amount of these will result in tough and non-elastic gluten. To supply these enzymes, properly malted, wheat flour is used or the requisite quantity of malt extract is added to the dough. Most of the smaller bakeries in India, however, use flour without any discrimination. The bigger bakeries generally use matured and bleached patent Indian or Australian flour. In making dough, 60 lb. of water are added to 100 lb. of flour ; the dough should be neither too stiff nor too sticky.

Yeast is the most suitable fermenting agent. The yeast zymase develops fermentation in the dough, producing carbon dioxide and alcohol. The former causes the dough to rise, and the latter is expelled during baking. Only the most up-to-date bakeries use compressed or active yeast.

Generally, 1 lb. of yeast is needed for treating 100 lb. of flour. Compressed yeast is dissolved in water at 80-85° F., and kept for an hour before use. With active dry yeast, the ferment is prepared by mixing 1 lb. of yeast, 7 lb. of water and 3 oz. of sugar at 80-86° F. Certain types of dry yeast are first brought to an active condition by mixing 1½ lb. of sugar, 2 lb. of flour and 1½ gal. of water with every lb. of yeast and allowing the mixture to stand for an hour before use. Other fermenting agents used for inferior grades of bread are milk, curds, toddy, etc.

Sugar is added to impart sweetness and flavour, to help fermentation and to increase the cal. val. of bread. It also gives the characteristic colour to the crust. About 5-6 lb. are needed for 100 lb. of flour. Salt is an essential constituent, since it controls fermentation by toughening the gluten, prevents bacterial growth, and gives taste and flavour. About 20-24 oz. are used for 100 lb. of flour.

The usual fat content of wheat flour (2-3 per cent.) being sufficient, no extra fat is added in preparing ordinary bread. For buns, rolls, etc., some extra fat (*Vanaspati*, lard or butter) is used. For greasing bread pans and for brushing baked loaves, hydrogenated fat or salad oil is used. Milk powder is sometimes added to enrich bread.

The straight dough method or the sponge and dough method is used in the manufacture of bread. These differ only in the method of mixing. The former is more common in India. It consists in mixing together all the ingredients at about 80° F. The quality of bread depends on thorough mixing of the ingredients and on proper kneading. This is carried out mechanically in large bakeries, but by hand in small bakeries. The kneading machine consists of a slow rotating vessel in which the flour is worked by means of a number of moving arms. The ferment is added during kneading and salt is added after the preliminary rising of the dough.

The kneaded dough is kept covered with a moist cloth for 3-5 hrs. for fermentation. During this period, the dough is cut at intervals to expel gases. Proper control of time and temperature of fermentation is necessary to give the dough the right degree of ripeness. The fermented dough is again worked with salt for about half an hour in the kneading machine, when stale gas is expelled. The dough is then divided into smaller pieces of the desired weight. These are rounded up with dry flour which gives them a surface skin. After about 15 min. they are squeezed to expel accumulated gas, rolled to proper shape and placed in greased blacksheet moulds or pans. The moulds are then kept for proofing in a warm place near the oven, for about an hour, when the dough rises almost to the top of the mould. The surface skin prevents the escape of gas during proofing.

The proofed loaves are then baked. Some fermentation continues during the early stage of baking, but at 140-145°F., it ceases. As baking proceeds, the alcohol produced during fermentation is expelled, the protein is coagulated and the starch is gelatinized. Dextrin formed at the top of the bread is caramelised, imparting to it a deep brown colour. In India, the bigger bakeries use the modern type of coke-fired draw plate ovens, but do not yet use the improved, continuous gas-heated ovens, with temperature control. Most of the smaller bakeries still use a primitive type of oven, heated by burning wood. The ashes are removed to one corner, and the dough in moulds placed inside. Once heated, the oven is generally good for the whole day.

The baked loaves are removed from the oven, brushed with butter, *Vanaspati* or salad oil to give the glaze and to prevent cracking, cooled for 2-3 hrs., stripped from moulds, and finally packed in waxed paper.

In the sponge and dough method, part of the flour and water and the whole of the yeast are first doughed and then allowed to ferment ; the sponge so formed, is broken and well mixed with the rest of the ingredients. Subsequent operations are the same as in the straight dough method. This process requires less yeast, less proofing, etc., but is hardly used in this country.

Bread, not meant for immediate consumption, should be wrapped in moisture-proof paper to prevent loss of moisture, so that it may not get stale. Loss of moisture, however, is an accentuating factor and not the cause of staleness. Precautions taken during bread-making help in arresting staleness. The dough should not be made too stiff or too warm and should never be over-proofed. Addition of oils, fat and malt extract, tend to delay staling. Freezing to a low temperature also prevents staling.

Bread is easily liable to infection by moulds. The mould-free life of bread can be increased by 7-8 days, if 2.5-5 oz. of propionates (calcium or sodium) are incorporated with 100 lb. of flour. Sodium diacetate serves equally well. Bread also develops 'rope' due to bacilli of the *B. mesentericus* group. 'Rope' in bread can be avoided by increasing the acidity with lactic acid, vineger or calcium phosphate. Sodium diacetate is also effective against 'rope' (von Loesecke, 265 ; Jacobs, II, 400).

White bread is usually manufactured in 3 sizes, ¼ lb., ½ lb., 1 lb., and in bigger sizes such as sandwich bread (3 lb. loaves). Other varieties, containing various enriching substances are, raisin bread (containing more sugar and raisins), brown bread (made of whole meal flour and malt), dinner rolls (containing milk and eggs), and milk rolls (milk replacing part of water).

BISCUITS

The use of biscuits is very limited in this country but their popularity is increasing. Britania Biscuit Co., the first organized factory to be started in India, commenced production in 1897, in Calcutta, and subsequently established another factory in Bombay. Their total capacity is about 5,160 tons per annum. This was closely followed by the Delhi Biscuit Co. (1898) with an annual capacity of 750 tons. Before World War II, six factories were started, of capacity varying from 250-1,200 tons. During the War, two more of 900 tons capacity each sprang up. Besides these, there are now 5 smaller factories and numerous small concerns to satisfy local demand. Most of the factories are situated in large cities and towns, and the industry received considerable stimulus during the two wars.

India at present produces only 'plain,' 'slightly sweet,' 'sweet,' 'short,' and to a smaller extent, fermented biscuits. The plain type includes cheese, milk, and water biscuits. These contain little, if any, sweetening agent, and a small proportion of fat. Slightly sweet biscuits, such as Thin Arrowroot, Marie and Petit Beurre, contain 20-25 per cent. of sugar and 16-18 per cent. of fat. The sweet type contains a much higher proportion of sugar. These are the cream sandwiched, the sugar-coated and the 'Ginger Nut' biscuits. Short biscuits contain a high percentage of fat and sugar.

For biscuits and crackers, especially for plain, slightly sweet and fermented types, the most suitable flour is one which contains a medium proportion of soft and silky gluten. Flour from Indian wheat containing tough and rubbery gluten, although in smaller proportions than in hard flour, is still considered hard. It is, however, quite suitable for the 'short' and to a smaller degree for the 'sweet' types. The Indian biscuit industry, therefore, prefers imported Australian flour for certain types. Correct blending and standardization of flour is also essential for uniformity and quality. The flour should be fresh-milled, free from added phosphates and chemicals, and should have creamy white colour with no large specks of bran. It should normally contain: moisture, 12; ash, 0.40; protein, 11 per cent. The moisture content should not exceed 13 per cent., and dry gluten should not be less than 10 per cent.

Sugar breaks the gluten, and also acts as an anti-oxidant for fat and increases the keeping qualities. Shortening or fat is another essential ingredient. It breaks the gluten and gives crispness to the biscuit by leavening it, and by giving it a flaky structure. Sufficiently large percentages are required to prevent dry gluten forming a hard mass. *Vanaspati*, preferably without 'grains,' margarine, lard or oil can be used, but in India only *Vanaspati* is used. Its characteristics should be m. p., 36-39° ; free fatty acids, 0.25 per cent. ; iod. val., 65 ; R. M. val., 1 per cent. ; Polenske val., 1 per cent. and impurities, less than 1 part in million. While *Vanaspati* is otherwise suitable, it does not give as soft or as short a biscuit as some of the best grades of imported biscuits. It is considered that the use of animal fats in the mixture brings about the desired improvement. According to Indian practice, 1 ton of biscuits requires on an average, 2,000 lb. of flour, 410 lb. of sugar, and 300 lb. of shortening.

In addition to fat, ammonium carbonate is generally used as a quick acting leavening agent. Sodium bicarbonate, yeast, and baking powder are also used in some varieties. Small quantities of glucose are used, in order to bind the dough and give sweetness to it. Honey produces a very rich colour and salt is added for taste. The other materials used are flavours and vegetable colours.

The industry requires high quality moisture-proof packing materials, for preserving the crispness and the quality of the biscuit. The packing materials in use are waxed paper, butter paper, cardboard, and tin-plates.

The manufacturing process consists in introducing wheat flour and sugar in requisite proportions, along with the other ingredients, into a vertical or drum mixer, the former being used for biscuits of the fermented and short types, and the latter for others. Here they are mixed and kneaded mechanically to a comparatively stiff but pliable dough. Salt, sugar, colours, and flavour, etc. are dissolved in water before being added to the flour. Ammonium carbonate is also added at this stage. The shortening is added when mixing and kneading is almost complete. The forming period varies with the class of dough required; hard doughs taking about 90 min., soft doughs 15-20 min., and cracker doughs, 20 min. The cracker, to which yeast is added, must lie for another 2-3 hrs. for fermentation and rising.

The prepared dough is first passed several times through the dough brake, consisting of a pair of steel rollers. The thick sheet of dough then passes through the reducing rollers, the finishing rollers, and finally through a high speed cutting and embossing machine. Dough for short type biscuits is not given any preliminary treatment in the dough brake. The scraps are taken back to the dough brake for reprocessing. The finished dough pieces are deposited on pans or trays and fed into the oven, which is a large gas-heated tunnel with temperature control. The biscuits are carried through the oven over a travelling chain or steel band at different speeds, depending on the type of biscuit and the temperature of the oven. Generally, 3-15 min. are required, but the time for baking may go up to 20-40 min. for very thick biscuits. Baking takes place at a temperature of 400-500°F. At an average temperature of 450°F., the baking time for most types of biscuits is about 12 min. The trays emerging from the oven are cooled by passing through a long air draft cooler. The biscuits are then sorted, the defective ones removed, and the rest packed.

In the case of cream biscuits, the cream or filling is sandwiched between biscuits. The filling generally used is a batter prepared from hydrogenated vegetable shortening, sugar, milk powder, colours and flavours.

Biscuits are usually packed in paper packets or cartons, care being taken to protect them by means of grease-proof or butter paper. The usual sizes are ¼, ½, one and two lb. packets. Sealed tin packings are the best, but there is scarcity of these at present. The cheapest method of packing is to pack them loose in bulk into large 4 gal. tins containing 10-18 lb. of biscuits. Generally, 1 lb. of biscuits contain 60-90 pieces, depending on the type. Very thick biscuits prepared for the Army, such as *Shakapara* biscuits, weigh 16 to a lb.

Before World War II, India was producing mainly second quality biscuits. During the War, due to stoppage of imports, the industry made great strides both in quality and quantity. Some of the leading firms are now producing certain types which compare favourably with the first quality foreign brands.

Before the War, the average wholesale price of the better class biscuits, sold in bulk containers, was As. 10 per lb. There was a steady rise in selling prices during the War due to complete stoppage of imports, and diversion of production to military requirements. The wholesale selling prices of manufacturers (1947) vary from As. 15 to Rs. 1-8 per lb., loose.

During the War, 13 factories supplied 34,238 tons of army biscuits (*Shakapara* biscuits), of which those in Bengal and Bombay supplied 13,644 and 11,486 tons respectively (Food Statist. India, 1946, 181). The present production capacity of the existing factories has been estimated at 27,000 tons, but due to insufficient supply of flour, most of the factories are working on single shift and are producing only one-tenth of their capacity. The Government of India is proposing to increase the total annual production to about 40,000 tons, by '52.

The pre-war annual consumption of biscuits has been estimated at about 9,000 tons.

AVERAGE ANNUAL IMPORTS OF BISCUITS AND CAKES INTO INDIA

	Cwt.	Rs.
In quinquennium ending '33-34	44,837	36,62,038
" '38-39	44,924	32,13,825
" '43-44	10,852	10,35,347
In '44-45	29	6,675
" '45-46	156	19,283

The imports are mainly from the U. K., and are subject to a revenue duty of 30 per cent. *ad valorem*.

CAKES

In India, cakes are generally prepared in restaurants and by confectioners. Smaller bakeries also produce cakes, but of inferior quality.

The essential ingredients of a cake are good flour, sugar, fat, baking powder and eggs. Along with these, milk, salt and flavours are also used. The optional materials are almonds, raisins, custard, etc. The usual proportions of the ingredients are : flour, 25-30 ; fat, 13 ; sugar, 25 ; eggs, 15-18 ; baking powder, 0.7-0.9 parts by wt. ; and milk as required.

For preparing a good cake, it is necessary to have soft flour with low protein content. It must be capable of forming enough gluten to hold the cake together, and to give it a cellular structure. For high sugar cakes, the flour should have a protein content of 7.5-8 per cent., and for soft cakes, 8.5-9.5 per cent. The fat should cream well and is primarily responsible for the cellular structure. Generally, hydrogenated fat or butter is used. The latter gives a more attractive flavour. The sugar softens the dough and remains in a dissolved or syrupy condition.

In most cases only eggs and milk are used for moistening the batter. The former functions also as a leavening agent. Eggs are beaten into a foam-like mass which remains stable till the gluten sets during baking. Baking powder is also added for leavening.

Cakes are of three kinds : yellow, white, and sponge cakes. The first two are similar. In white cakes, only egg white is used. They have a finer grain. but they rise less during baking.

Soft cakes are made by the sugar batter method in which sugar and fat are first creamed and then mixed with egg, flour and milk ; and cakes of finer grain and texture, by the flour batter method, in which flour and fat are creamed together, and later mixed with eggs and sugar batter. In the single stage method of preparing cakes, all the ingredients are mixed together at the same time. The cake produced does not possess the same volume, as those produced by the other two methods. The prepared batter is put in cake pans of various shapes and placed in baking oven. The baking temperature is 300-400°F. The time required for baking depends on the type, size and shape of the cake. The cakes after being baked are cooled and covered with special compositions and finishes.

BARIUM COMPOUNDS

The chief commercial salts of barium are the chloride, the carbonate (*vide infra*), the nitrate and the sulphate. Barium nitrate which gives a green colour to flame is used in pyrotechnics, and for green flares and signals. Precipitated barium sulphate, also known as *blanc fixe*, is a valuable base and extender in the paint industry. A specially purified sulphate, free from any trace of soluble barium compounds, is used in the X-ray examination of the alimentary tract. Barium sulphide is sometimes used as a luminous paint due to its feeble phosphorescence, and as a depilatory.

The minerals witherite ($BaCO_3$), and barite ($BaSO_4$) are the sources of barium compounds. From the former, they are readily obtained by treatment with corresponding acids. Barite is reduced to barium sulphide by roasting it with powdered coke or charcoal, and the latter is processed to yield barium salts (*vide J. sci. industr. Res.*, 1944, **3**, 108).

In India, the production of barium compounds started during the last War. The Mettur Chemical and Industrial Corpn. have a plant capable of producing up to 1 ton per day of barium salts, chiefly the chloride. Since witherite does not occur in India, they use barite as raw material.

BARIUM CARBONATE

Barium carbonate, $BaCO_3$, is a white powder which decomposes at a very high temperature (1360°). It is prepared from barium sulphide by passing carbon dioxide through its solution, or by treating it with sodium carbonate. Although insoluble in water, it is poisonous, as it is acted upon by acid in the stomach which converts it into a soluble salt.

Barium carbonate is used in the manufacture of optical glass, china and porcelain, and enamels for ironware. It is an effective rat-poison, and the bait is usually prepared from barium carbonate, 6 oz. ; common salt, 1-4 oz. ; wheat flour 4 oz. ; pea or *bajri* flour (*Pennisetum typhoides*), 12 oz. ; and dripping, 4 oz. (Kingzett).

BARIUM CHLORIDE

Barium chloride, ($BaCl_2 . 2H_2O$), is a colourless crystalline salt. It is readily soluble in water and is highly poisonous. It loses its water of crystallization completely at 100° and melts at 860°. Unlike the chlorides of calcium and strontium, it is not hygroscopic.

Barium chloride is used for the preparation of precipitated barium sulphate. It is also employed in leather tanning, in boiler compounds, and in water softening.

In India, its principal use is for the removal of sulphates from brine solution used for the electrolytic manufacture of caustic soda. The Indian Alkali Industry, when producing 45,000 tons of electrolytic alkali, will require 1,000-1,500 tons of the salt (Rep. Heavy Chem. and Electro-Chem. Industr. Panels, 1947, 26). This demand will decrease when purer salt becomes available.

Barium chloride is manufactured in India by the Mettur Chemicals. Powdered barites and charcoal are mixed with a 50 per cent. solution of calcium chloride and heated to 800-850° in a reverberatory furnace for about six hours. The products of the reaction are lixiviated with water, the clear solution treated with a small quantity of hydrochloric acid or chlorine to remove soluble sulphides, and concentrated. The crude crystals that separate on cooling are recrystallized, and dried in a hot air drier (Shah, *J. sci. industr. Res.*, 1946, **4**, 788).

Small quantities of barium chloride are also produced by the manufacturers of electrolytic caustic soda.

EXPORTS OF BARIUM COMPOUNDS (EXCLUDING BARIUM PEROXIDE, BARYTES AND *BLANC FIXE*) FROM U.K. TO INDIA *

Year	Tons	£
'40	270	4,934
'41	219	5,350
'42	83	1,817
'43	72	1,780
'44	99	4,194
'45	265	8,393

* *Tr. U. K.*, III.

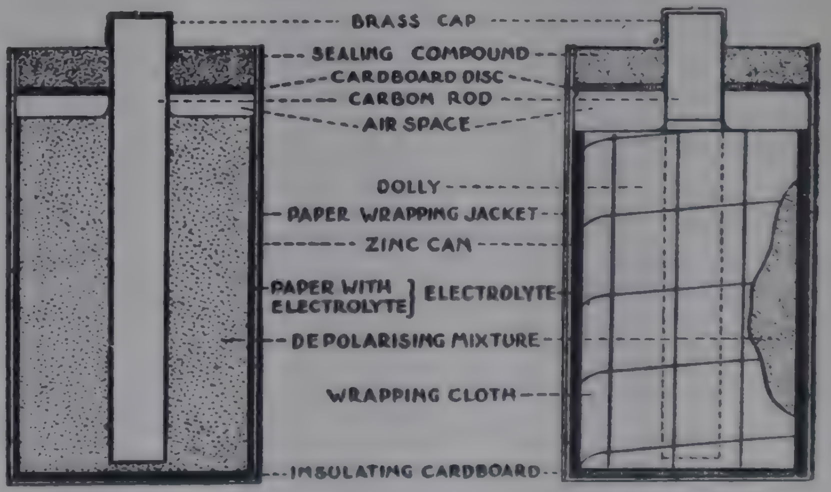
BATTERIES AND ACCUMULATORS

Batteries and accumulators are devices for generating electrical energy by chemical reaction. They are assemblies of primary or secondary cells, to give higher output of energy. Primary cells, such as dry cells, produce electrical energy by chemical reaction which is not easily reversible. Secondary cells depend upon reversible reactions for their operation. These cells are always assembled into batteries, as in the lead acid storage battery.

DRY CELLS

A dry cell is a Leclanche cell in which the electrolyte is in the form of a paste, and cannot be spilt. The cell consists of an anode of carbon rod surrounded by a mixture of depolarizer and electrolyte, the entire assembly being sealed in a zinc container, which serves as the cathode. The sealed cell is insulated by covering it with paper. It is essential to construct it in such a way that the electrolyte is always kept sufficiently moist.

Dry cells are of two types : the packed type,. and the bag or dolly type. In the former, absorbent paper soaked in electrolyte, is pasted to the inner surface of the zinc container ; the depolarizer, moistened with the electrolyte, is pressed round the carbon rod placed centrally in the container. Generally, larger cells are constructed in this manner. In the dolly type, as in flash-light cells and other small sizes, the carbon rod surrounded by a mixture of depolarizer and electrolyte, is compressed into a dolly, wrapped in muslin, and introduced into the container along with the electrolyte. ' Inert cells ' are manufactured dry, and require the addition of water before use.



Packed Type Cell. Bag Type Cell

The reactions taking place in a dry cell during discharge are summarised in the following equation :

$$Zn+2NH_4+Cl_2+2MnO_2=Zn(NH_3)_2Cl_2+H_2O+Mn_2O_3$$

During discharge, hydrogen liberated by the action of zinc on ammonium chloride, accumulates on the internal surface of the container, giving rise to polarization which retards further action. Manganese dioxide acts as a depolarizer by oxidizing it to water. A well-constructed dry cell should show an e. m. f. of about 1.5 volts, its output depending upon its size. It should be capable of being stored for several months without deterioration.

Due to their portability and ease of working, dry cells are extremely convenient sources of electrical energy. These are extensively used in flash-lights (torches), medical instruments, post and telegraph equipment, and various electrical appliances. The Army requires them for signalling lights, field telephones, radio and aircraft communication instruments, etc.

In the manufacture of dolly type cells, rolled zinc sheet or ribbon is used for the container ; it should have sufficient tensile strength, and stiffness to withstand manufacturing operations. Impurities such as lead, cadmium, copper, iron, arsenic, antimony and tin, should be as low as possible to enable it to resist the corrosive action of the electrolyte. It is amalgamated by treatment with a weak solution of mercuric chloride, to increase its corrosion resistance and to prevent pitting of zinc. Generally, sheets of 6-8 gauge No. (0.012-0.016″ thick) are used for flash-light cells, and thicker sheets, for cells of longer life.

The materials used in the manufacture of the dolly, which is the composite anode, are carbon rods, manganese dioxide, acetylene soot and lampblack. The carbon rod should be straight, dense, and of good mechanical strength. It should have longitudinal surface grooves, for better contact with the depolarizing mixture. It is usually manufactured from coke or retort carbon of high purity (ash content, 5 per cent.), and very low electrical resistance. The rod is generally lightly paraffined, in order to prevent creeping of the electrolyte to the brass cap.

The efficiency of manganese dioxide, as a depolarizing agent, depends upon its chemical composition and physical structure, such as particle size, crystalline state, etc. The ore (pyrolusite, psilomelane, etc.) should be free from metallic impurities, and is ground to 60 mesh. In many cases, the addition of artificial manganese dioxide, up to 10 per cent. of the ore, enhances its depolarizing action.

Graphite, up to about one-fourth the wt. of manganese dioxide, is used to increase the electrical conductivity of the latter. Flake graphite is preferred, but usually a mixture of crystalline and amorphous varieties is used. It should have a minimum carbon content of 85 per cent. with the following limits for impurities ; Fe, 2.5 ; Cu, 0.03 ; Ni and Co, 0.03 ; As and Sb, 0.03 per cent. ; ash, 10 per cent. ; and at least 85 per cent. of it should pass through 200 mesh sieve (*Industr. Chem.*, 1947, **23**, 31).

Acetylene soot is added in small quantities to the depolarizing mixture for increasing its porosity. It should not exceed 5 per cent. by wt. of the total carbon content. Finely-divided lampblack is also added in small quantities for assisting contact between the relatively larger particles of manganese ore, graphite particles, and the electrodes.

The electrolyte is a paste consisting mainly of ammonium chloride, zinc chloride and a gelatinising substance. Ammonium chloride, which is the main ingredient, should be free from copper and iron, as these would settle on zinc and form harmful local galvanic cells. Usually, white powdered commercial grade, containing less than 1 per cent. ash, and an equally small percentage of moisture, is used. Some dry ammonium chloride (10-15 per cent. of the wt. of the dolly) is also added to the depolarizer.

The electrolyte consisting of a 20°/₀ solution of ammonium chloride, has a severe corrosive effect on the container. Zinc chloride (7-10°/₀) is added to resist its corrosive action, as it minimises local action.

Small quantities of calcium chloride (2-3 per cent. of paste) and magnesium chloride are added to the electrolyte, on account of their water-retaining properties, and also some mercuric chloride to effect amalgamation of zinc and to prevent the growth of moulds and micro-organisms in flour or starch. Gelatinising substances, for preventing spilling of electrolyte, are mostly flour and starch, although agar-agar, gum tragacanth, and plaster of Paris are sometimes used.

Zinc cups or cans are prepared either by rolling or drawing. Smaller sizes, such as those used for flash-light cells, are made by soldering rolled pieces with blanked bottom discs. The cups are grooved about $\frac{1}{4}''$ from the top, to make a seat for the top cardboard washer, over which the sealing compound is poured. A paraffined star-shaped cardboard is inserted at the bottom of the can for insulating the dolly from the can.

To prepare the depolarizing mixture, manganese dioxide, graphite, soot and lamp-black, together with some ammonium chloride and zinc chloride are mixed in rotating drums, and moistened with the requisite quantity of water. The mixture is then forced through a sieve to eliminate small lumps formed during mixing. For preparing dollies, this mixture is pressed round carbon electrodes ; or the electrodes are forced into cylinders moulded from it. The dollies thus prepared are wrapped firmly with cloth and tied with twine.

The electrolyte is prepared by dissolving the required chemicals in definite proportion, and adding the gelatinising substance slowly, while the solution is thoroughly stirred. In building the cell, the dolly is dipped in the electrolyte to wet the cloth and to expel air bubbles, and inserted into the can. It is centered and held *in situ* by means of cardboard washers. The prepared electrolyte is poured into the can, up to the top edge of the dolly ; it should not touch the carbon rod. The exposed portion of the carbon rod is lightly paraffined on the outside, and its upper end fitted with a brass cap. The electrolyte is usually gelatinised round the dolly *in situ* by heating the cells in a water bath at a suitable temperature. The cooked cells are quenched in cold water and left open for 24 hrs., before sealing with shellac or bituminous composition. Sometimes self-gelatinising electrolytes are used.

The cells are next wrapped in paper, or placed in cartons and labelled. For batteries, unwrapped cells are assembled in a box separated by paraffined cardboard strips, the intervening space being filled with sealing compounds. Brass strips are soldered to the terminals to make inter-cell connections. Sometimes a vent hole is provided to allow ammonia to escape.

Finished cells are subject to regular control and service tests. A defective cell is usually detected by momentarily short-circuiting it through a low resistance dead-beat ammeter and noting the maximum deflection of the needle ; such cells give lower readings. A certain proportion of finished cells, selected at random, is subjected to service tests, which include measurement of open circuit voltage, internal resistance, polarization, output capacity, and shelf-life tests. Good cells have a life of 18-24 months.

The first dry cell factory in India was set up in 1926 by the Eveready Co. of the U. K. at Cossipore, Calcutta. In 1936, it was taken over by the National Carbon Co of U.S.A. under the name, National Carbon

Co. (India). Messrs. Jesco Chemicals and Allied Industries, Bombay, commenced production in '36, and in '39, the company was renamed Estrella Batteries Ltd. Before the last war, these two were the only companies in existence, and are now the largest producers of dry cells in India. Subsequently, two other concerns, Baroda Batteries Ltd., Baroda, and Amco Ltd., Bombay, of smaller capacity, came into existence. During the War, Indian production was sufficient to meet the greatly expanded demand. Amco Ltd. stopped production in '42, but expect to resume work in '48. Two other factories, one at Bombay with a capacity of 15 million cells per year, and the other at Lahore with a capacity of 5 million cells, are also expected to commence production in '48.

Most of the materials used in the industry (over 75 per cent.) are imported. These include zinc sheets, carbon rods, manganese dioxide, graphite, lampblack and soot, chemicals, brass caps and solder. Before the War, the annual imports were valued at Rs. 10 lakhs. During the War, the U. S. A. exported them to India under the Lease-Lend Agreement.

Indian manganese ores have not been used much in dry cells, and manufacturers have been importing the ore from the Caucasus, Java and Africa. Joglekar, Subba Ramiah and Verman (*Bull. Indian Industr. Res.* No. 23, 1941) have shown that some ores from the C. P., and Mysore, after suitable treatment, may be utilized in this industry. The powdered ore is roasted with caustic alkali (10 per cent.) and an oxidizing agent (5 per cent.). It is then washed with water to remove soluble materials and is again roasted in air (Indian Pat. No. 28135). The ore thus treated may be used as a depolarizing agent, without the addition of artificial manganese dioxide. The Baroda Batteries are now using indigenous ore. Ceylon graphite is extensively used in India. The ash content of Indian graphite is too high Artificial graphite which is also employed in dry cell manufacture is not produced in India.

At present, only dolly type cells are manufactured in India. Most of the concerns use semi-automatic or hand-operated machines, and only the N. C. C. has a completely automatic plant. Semi and fully-automatic machines, although requiring heavy initial investment, are economical for higher output and give a better product, but they require systematic and expert attention.

The products manufactured at present include flash-light cells; radio batteries, big mono-cells, small dry cells, sac elements (dollies), and inert cells (cells without water). The so-called standard cell (diam., $1^{3}/_{8}''$; length, $2^{3}/_{8}''$) is manufactured in very large numbers. Special cells for aircraft communication and signalling are made by a few firms. During the War, about 80 per cent. of production was reserved for defence purposes. Most of the products are being sold within the country.

The pre-War production of dry cells was 18 million cells. In '44, it was 101 million cells of which about 75 per cent was manufactured by the N. C. C. and the remainder by the Estrella Batteries. In '46, production dropped to 88 million cells, consisting of 71 millions by the N. C. C., 16 millions by the Estrella, and 0.23 million by the Baroda Batteries. It is expected that by the end of '50 production will increase to 150 million cells per year, valued at Rs. 250 lakhs. The capital invested in the industry is about Rs. 88 lakhs, and it gives employment to over 2,500 men.

Indian manufacturers are now able to compete with the best imported varieties, both in quality and in price. Before the War, they experienced serious competition from the U. S. A., Germany, China and Japan. The quality of the Chinese and Japanese products was not high, but they were sold at very low prices.

AVERAGE ANNUAL IMPORT OF DRY CELLS INTO INDIA

		Lakhs of Rs.
Quinquennium ending	'33-34	12.81
,,	'38-39	21.63
,,	'43-44	8.07
In	'44-45	3.07
,,	'45-46	5.12

Most of the imports are flash-light batteries. Special batteries are imported only to a small extent. In '38-39, the val. of the former was Rs. 19.6 lakhs, and of the latter, Rs. 1.9 lakhs. During the quinquennium ending '38-39, the U. S. A. supplied 70 per cent. of total imports, followed by Germany (14 per cent.), China—including Hongkong (7 per cent.), U. K. (7 per cent.) and Japan (2 per cent.). Imports of dry batteries are subject to a revenue duty of 30 per cent. *ad valorem.*

ACCUMULATOR OR STORAGE BATTERY

A storage battery consists of two or more secondary cells, connected in series, and manufactured as one unit. A storage cell consists of two dissimilar electrodes or poles immersed in an electrolyte.

The two commercial types of storage battery are lead-acid cells, and alkaline cells. In the former, the positive and negative electrodes are made up of lead peroxide (PbO_2) and spongy lead respectively, and are immersed in the electrolyte (dil. sulphuric acid). The peroxide and this spongy lead are held in grids, made of lead-antimony alloy.

Alkaline cells are of two kinds, the nickel-iron type (Edison cell) and the nickel-cadmium type (Jungner cell). In the Edison cell, the positive consists of nickel peroxide, and the negative, mainly of iron. In the Jungner cell, the positive is nickel oxide mixed with high conducting graphite, or nickel flakes ; the negative is a mixture of iron and cadmium oxides. The electrolyte in both is a solution of potassium hydroxide with small quantities of lithium

EXPORT OF DRY CELLS FROM U. S. A. TO INDIA

(No. in thousands and val. in thousand dollars)

	Dry cell batteries		Flash-light batteries		Dry multiple cell batteries except flash-light		Other dry and wet cell primary batteries	
	No.	Val.	No.	Val.	No.	Val	No.	Val.
40 ..	16	2.7	6,895	1,849	87	39	..	..
41 ..	56	10.7	38	11	90	43	..	..
'43 ..	30	6.2	155	78	2,560	878	752	5,769
'44 ..	32	21.4	1,042	490	3	0.4	1,930	15,821

Exports in '43 and '44 were almost completely under Lease-Lend Agreement.

hydroxide, in a steel container. The active materials are packed in perforated tubes and pockets, supported in grids.

The reactions taking place in the lead-acid cell during charge and discharge may be shown as below :

$$\overset{+}{\mathrm{Pbo_2}}+2\mathrm{H_2SO_4}+\overset{-}{\mathrm{Pb}}\ \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}}\ \overset{+}{\mathrm{PbSO_4}}+2\mathrm{H_2O}+\overset{-}{\mathrm{PbSO_4}}$$

The charged cell therefore consists of a plate of lead, and a second plate of lead peroxide separated by a porous separator through which sulphate ions can migrate. Sulphuric acid is used up during discharge, and this brings about a decrease in the sp. gr. of the electrolyte. During charging, on account of the reverse reaction, sp. gr. increases. The state of charge of a cell can be readily determined by measuring sp. gr. of the electrolyte.

Sulphuric acid attacks the electrodes even when the cell is idle, and slowly converts lead into lead sulphate, resulting in gradual loss of capacity. These cells require routine maintenance, both during active and idle periods.

In the alkaline cell, the reaction may be represented by the following equation :

$$\overset{+}{\mathrm{NiO_2}}+2\mathrm{KOH}+\overset{-}{\mathrm{Fe}}\ \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}}\ \overset{+}{\mathrm{NiO}}+2\mathrm{KOH}+\overset{-}{\mathrm{FeO}}$$

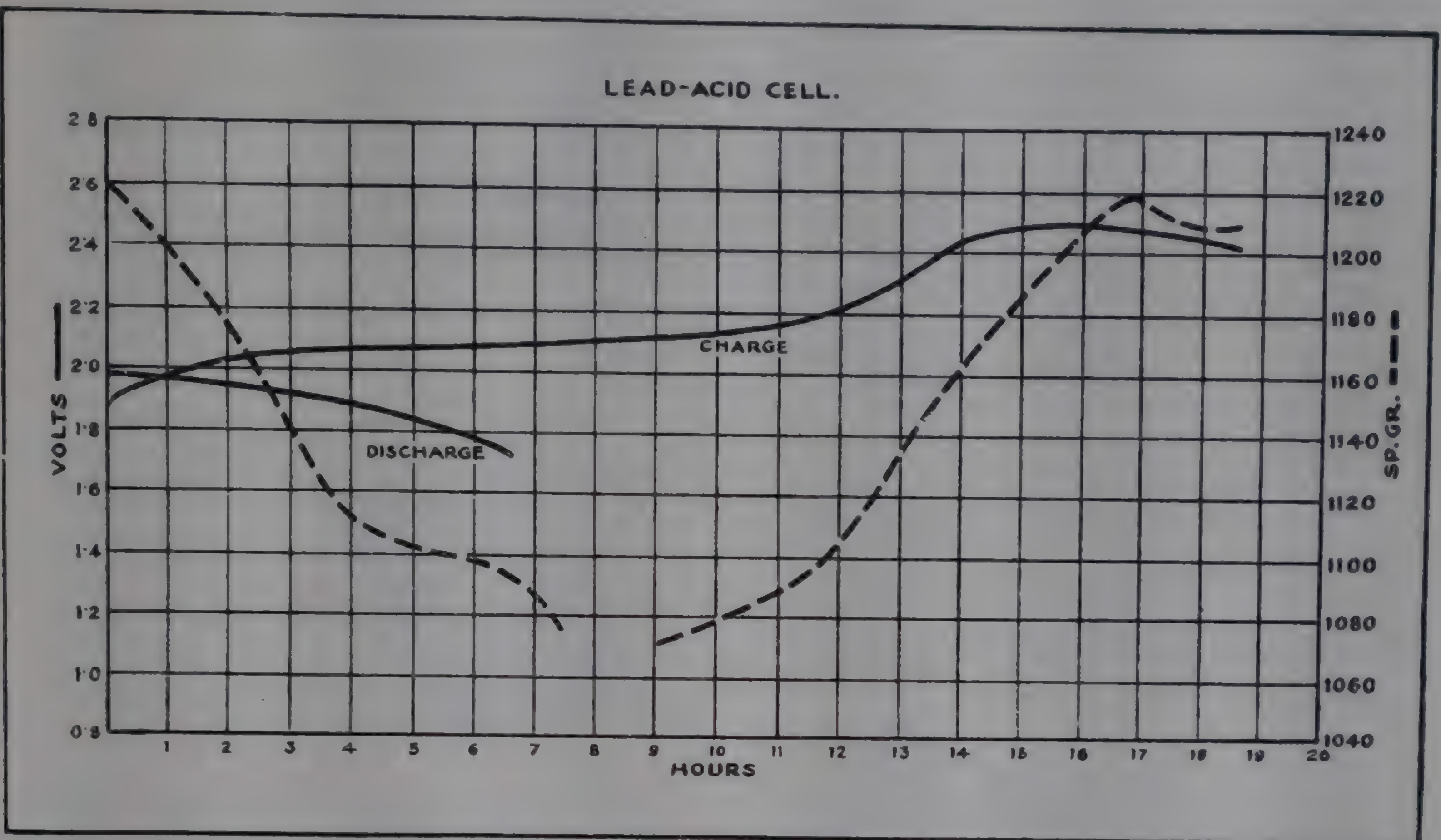
During charging, NiO of the positive plate is oxidized to a higher oxide of nickel, NiO_2, and ferrous oxide in the negative plate is reduced to metallic iron, oxidation and reduction being brought about by oxygen and hydrogen liberated at the respective poles by electrolytic decomposition. The reaction during discharge is merely the reverse. The electrolyte does not undergo any change, and this makes it difficult to find out the state of charge of a cell. In this type of cell, no reaction takes place during the idle period, and hence it can be left unattended to for a long time.

Each cell consists of positive and negative plates varying in number and size, according to capacity, and connected in parallel. Lead-acid cells are divided into two types based on plate structure ; these are the Plante′ type, and the Faure pasted plate type. In the former, the active material is formed electro-chemically from lead of the plate, whereas in the latter, the active materials are pasted to lead grids which act as supports. The pasted plate may be of the ordinary flat type, or of the modified type (Exide-Ironclad) ; in the latter, the active material is used in the form of cylindrical pencils, enclosed in slotted rubber tubes, held in lead grids. This type of cell has come into extensive use, especially for electrical propulsion of trucks, tractors, etc., and in marine and other services.

In the alkaline type, the active material of the positive is contained in perforated tubes and is held in a grid. The negative plate is of similar construction ; the active material is contained in rectangular perforated steel pockets and fixed in a grid. Grids, tubes and pockets are made of nickel-plated steel. Alkaline cells are more robust than lead-acid cells and can stand vibration ; they are also immune to serious damage from negligence.

When fully charged, a lead-acid cell on open circuit has an approx. e. m. f. of 2.3-2.4 volts, regardless of its size, and an alkaline cell, about 1.8 volts. Automobile batteries consist of 3 or 6 lead-acid cells, containing 13 or 15 plates per cell, connected in series, and have a voltage of 6 or 12 volts. During discharge, the voltage drops down to 1.8 volts in a lead-acid cell, and to 1.1 volts in an alkaline cell. The batteries should not be worked beyond these limits, as repeated over-discharge would permanently injure them.

The capacity of a battery is the product of discharge current in amperes, and the time in hours during which the current could be drawn, and is expressed in ampere hours (amp. hr.). The capacity of a battery with cells in series is the same as that of a single cell, and that of a battery with cells in parallel is the sum of the capacities of all the cells. A 13-plate battery of 3 cells stores about 100 amp. hrs. of energy. A charged battery will deliver 80-90 per cent. of the energy used in charging, but as the battery becomes older, this efficiency drops sharply.

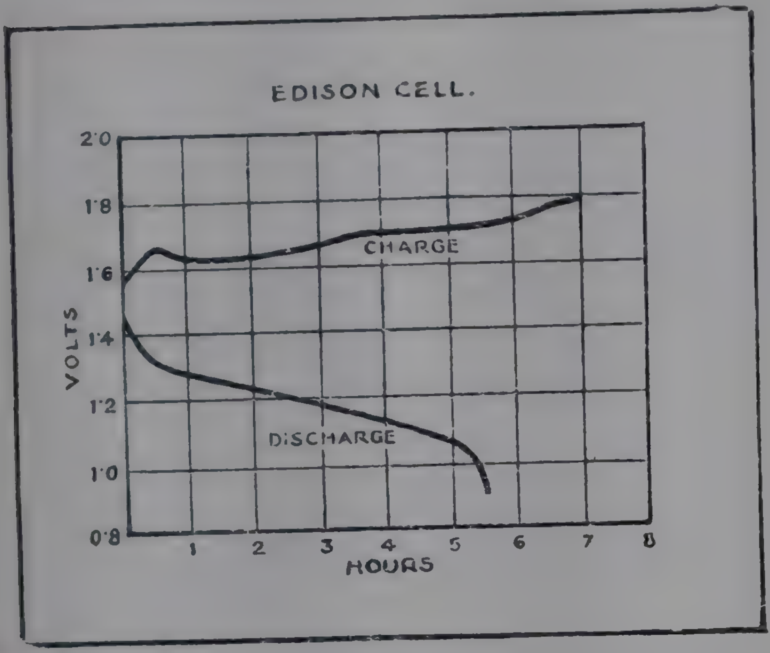


PERFORMANCE CURVE OF LEAD-ACID-CELL

Electric batteries or accumulators are used in widely varying fields. They find extensive application in automobiles, aircraft, marine service and railways; they are also widely used for radio receivers in areas where there is no power supply. Large stationary batteries of electric accumulators are used in hospitals, cinemas, etc., for emergency purposes. Telephone services also require a number of storage batteries.

The most important use of lead-acid accumulators is in automobiles where they are required for starting, lighting and ignition. The pasted plate type is universally used since it is capable of giving very high current, on account of its lower internal resistance. Automobile batteries are made of 3 or 6 cells connected in series and their capacity is about 100 amp. hrs. Diesel buses, with more difficult starting problems, require 12, 24, 30 or 32 volt batteries, containing 9-45 plates per cell. In railway coaches for lights and fans, lead-acid batteries are used with discharge capacity of 300, 270, 210, 150 and 100 amp. hrs. measured at the 10 hr. rate to a minimum of 1.8 volts per cell. Each coach is fitted with two batteries, each battery consisting of 12 cells (Indian Ry. Bd. Specif. E2A-39).

Lead-acid batteries are used for various stationary purposes, such as telephone operations, switch devices, operation theatres; and in marine service for ignition in internal combustion engines, for gunfiring on naval ships, and for submarine propulsion under water. Light lead-acid batteries with non-spilling electrolyte are used in aircraft for engine starting, lighting and radio. Reduction in weight is secured by altering the composition of grid materials, and design of grid, and by using light aluminium containers.

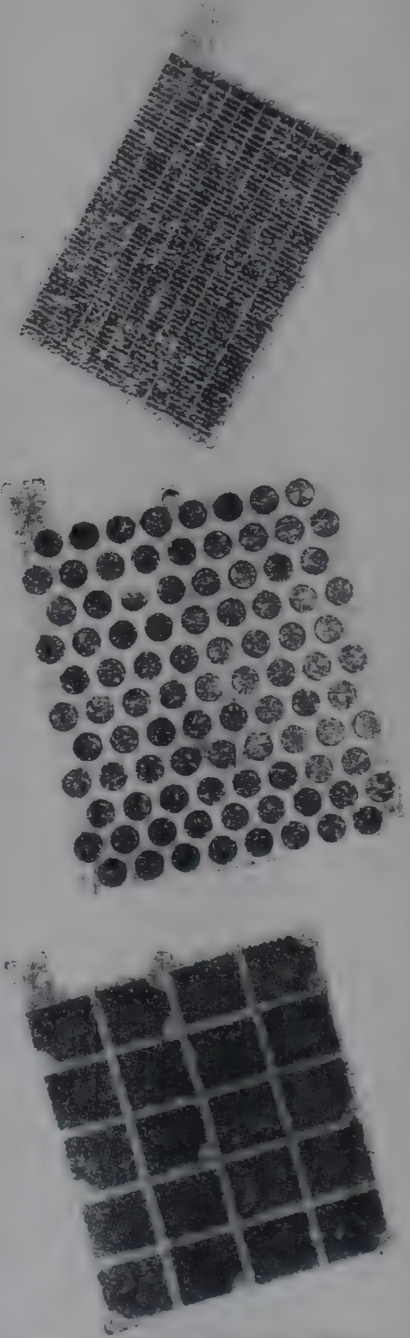


PERFORMANCE CURVE OF EDISON CELL

In India, alkaline batteries are only used in railways for coach lights and fans. Each coach is provided with 2 batteries, each containing 19 cells. For this purpose, alkaline batteries with discharge capacity of 300, 225, 150 and 100 amp. hrs. measured at the 10 hour rate to a minimum of 1.1 volt per cell, are used (Indian Ry. Bd. Specif., E2). This battery cannot be used for starting purposes, but is eminently suitable for motor operation and ignition. It delivers a moderate current, but is not capable of furnishing the peak surges for motor starting. Unlike a lead-acid cell battery, it is not injured by complete discharge. Its life varies from 7-20 yrs., depending upon service conditions.

The principal materials used in lead-acid cells are lead and antimony, litharge and red lead, sulphuric acid, containers and separators, and sealing composition. Others are vent plugs, terminal posts, connecting bars and straps, etc.

LEAD-ACID CELL



1-3. BATTERY PLATES
Courtesy of Messrs. Standard Batteries Ltd., Bombay

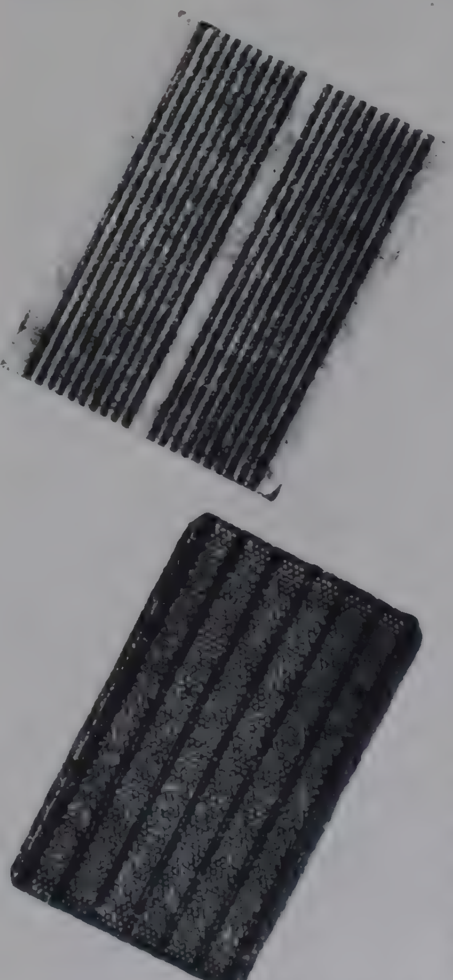
Grids of lead-acid cells, which act as supports for active materials, are made of antimonial lead, containing 5-12 per cent. antimony. Antimony improves the flow characteristics of lead in the mould, and gives sharp castings. Both lead and antimony of high purity (99.9 per cent.) should be used. Secondary lead from discarded batteries is also being increasingly employed; its antimony content is adjusted during melting and casting.

Grid interstices are filled with a paste made from lead oxides and dil. sulphuric acid. These materials are subsequently converted electrochemically into the active materials of finished plates. Both red lead (Pb_3O_4) and litharge (PbO) of high purity are used for making plates. Impurities in good grades of oxides for battery purposes are: SiO_2, 0.05; Ca, 0.05; Fe, 0.02; Cu, 0.01; Bi, 0.05; Ag, 0.001%; zinc, traces; and chlorine, nitrates and arsenic, nil (Vinal, Storage Batteries, 1940, 23). Apparent density, acid absorption, particle size distribution, etc. are important considerations. Litharge has the property of forming a cement when moistened with sulphuric acid. This property of red lead is not so good; it is therefore mixed with a small amount of litharge for making the paste. The composition should have sufficient porosity while maintaining cohesion and strength. Generally, a mixture containing 75 per cent. litharge and 25 per cent. red lead is used for negative plates; for the positive plates it is made with a large proportion of red lead, 50-80 per cent. Both red lead and litharge are at present manufactured in India, and in '44, the battery industry consumed 60 tons of litharge and 120 tons of red lead. Small amounts of expanders, such as lamp-black, *blanc fixe*, charcoal, wood flour, etc., are used with the paste for preventing solidification of spongy lead on the finished plate.

Sulphuric acid is used as electrolyte, and also for making pastes of active materials. It should be colourless and of exceptionally high purity (for specif. *vide* p. 23), and only distilled water is used for diluting it to the required sp. gr. When fully charged, the sp. gr. in the portable types is 1.25-1.30, and in stationary batteries, 1.20. Owing to the smaller size of the former, acid of higher strength is used to obtain the desired output of current. In India, the annual consumption of sulphuric acid (100 per cent.) by the battery industry is 410 tons (Rep. Heavy Chem. & Electro-chem. Industr. Panels, 1947, 2).

Battery containers and covers should be leak-proof and acid-resistant, and are made of hard rubber or ebonite, asphalt compositions, or glass. Hard rubber containers are employed for portable types, and those subject to mechanical shocks in service. These have raised ribs, fitted at the bottom or moulded with the container, meant for carrying and holding the plates in position. Glass gives better maintenance facilities and is used where size and service conditions permit, as in wireless and lighting plants. Lead-lined wooden tanks are invariably used for large stationary batteries and may also be used in smaller sizes. During the War, polystyrene plastics were tried in the U. S. A. Containers are usually divided into compartments of two or more cells, and the cover is provided with a number of openings for terminal posts, and vent plugs, for filling. Most of the containers and covers are imported. Recently a few firms in India have started the manufacture of hard rubber containers and lids.

Separators are placed between the positive and negative plates to prevent contact. They should be porous to allow the electrolyte to diffuse through them and to permit electrolytic conduction, and should maintain sufficient mechanical strength throughout the life of the battery. They may be made of perforated hard rubber sheets, porous rubber, glass, wood, etc.



BATTERY SEPARATORS
(*Courtesy of Messrs. Standard Batteries Ltd., Bombay*)

The essential requirements of wood for separators are permeability, straight grain, freedom from knots, and resistance to the action of the electrolyte. Any tannins, volatile acids or resinous matter present must be removed and this is done by boiling the separators in 1 per cent. solution of caustic soda for two hrs., followed by thorough washing. A subsequent treatment in a glycerine bath gives extra permeability and enables the separators to be stored without any danger of warping (*Indian For. Leafl.* No. 14, 1942 ; Trotter, 1944, 194).

Battery separators of wood are usually prepared from Port Orford cedar [*Chamaecyparis lawsoniana* (A. Murr.) Parl.], a North-American timber. Other woods used in the U.S.A. are basswood (*Tilia americana* Linn.), poplar (*Populus* spp.), some kinds of pine (*Pinus* spp.), Douglas fir [*Pseudotsuga taxifolia* (Poir.) Britt.], cypress (*Cupressus* spp.) and redwood, [*Sequoia sempervirens* (Lamb.) Endl.].

Among Indian woods *Cupressus torulosa* D. Don (Himalayan Cypress) and *Michelia champaca* Linn. (*Champ*), when properly treated, have been found to be as good as Port Orford cedar. *Adina cordifolia* Benth. Hook. f. (*haldu*) can be used where the batteries are not subject to mechanical shocks, but the wood is adversely affected by the electrolyte (*Indian For. Leafl.*, *loc. cit.* ; *Indian For. Bull.*, *New Series*, No. 124, 1944 ; Trotter, *loc. cit.*). Wooden separators are generally made from sawn veneers, and occasionally from peeled veneers. Grooves are cut on one side of separators to allow circulation of electrolyte, and free passage for sediment to settle. The wood should be properly seasoned and the moisture content should be maintained at 20 per cent. At present separators are mostly imported.

Other parts of a lead-acid battery are connecting bars and straps, terminal posts, vent plugs, etc. Two connecting bars are used to weld group of positive and negative plates in a cell. External connecting straps of lead or non-corrosive metal castings connect the cells of a battery in service. Terminal posts are upward extensions of connecting bars that pass through the holes of cell covers. These are for connecting the cells in series, or the battery with the mains. Vent plugs are screwed on to covers for prevention of spilling of acid, and for escape of gas. Blown asphalt of m. p. of about 200°F. is used for sealing cell cover to the container.

Alkaline batteries, although similar to to lead-acid types in construction, employ different materials. The grids, tubes and pockets, for active materials are made of nickel-plated steel. Materials used for filling tubes of positive plates are nickel oxide, flake nickel and graphite. The two latter increase the conductivity of the peroxide formed. The negative plate tube is filled with a mixture of metallic iron, ferrous oxide and mercuric oxide in Edison cells, and with a mixture of iron and cadmium oxides in Jungner cells. Caustic potash (15 per cent. solution) with a small quantity of lithium hydroxide is used as electrolyte. Its sp. gr. should be 1.19-1.25. Separators are made of hard rubber, and the container, of nickel-plated steel.

In the manufacture of lead-acid cells, plate grids are first cast from lead-antimony alloy. About 14 lb. of the alloy (Sb, 8-10%) are required for a 6 volt battery of 13 plates. The grids are 2-5 mm. in thickness, and are designed to hold the active material firmly, the usual designs having straight or diagonal cross bars. Machine castings are made for large-scale production. Negative grids are generally lighter than the positive grids as they are subject to less corrosion. Terminal posts, screws and conductors are similarly cast. Cast grids are trimmed to remove edges ; lugs which connect grids to connecting straps are cut to the required length. The grids are next cleansed with a wire brush, and the meshes pasted or packed tightly with a reasonably stiff paste of lead oxides and dil. sulphuric acid (sp. gr., 1.10 or less). Pasting is generally done by hand, but for large-scale production, machine pasting may be adopted. The pasted plates are dried to harden the paste, and carefully 'formed' electrolytically in a tank containing dil. sulphuric acid. The anode plates are connected to the positive, and the cathode plates to the negative supply terminals. During this process, the oxides in the anode are oxidized to lead peroxide, and those in the cathode, reduced to spongy lead. The formation of plates is sometimes carried out separately, using dummy plates for the second electrode. In large-scale manufacture 'forming' is done in assembled cells.

The formed plates are washed, dried and assembled into groups of positive and negative plates for cells, by burning plate-lugs to respective connecting straps, which in turn are burned to the projecting terminal posts. In building a cell, separators are placed between alternating anode and cathode plates. In every cell there is one negative plate more than positive plates. In a 13-plate cell, there are 6 positive and 7 negative plates, and 12 separators. The cell unit is inserted in the container, lids are put on and fixed to terminal posts by binding screws, and finally sealed with a sealing composition. A 6-volt battery consists of 3 cells connected by lead connectors burned to the projecting terminal posts. When a new battery is to be put to use, it is filled with dil. sulphuric acid of required strength and charged according to instructions of the manufacturer.

In the manufacture of alkaline cells, perforated tubes for positive electrodes made from nickel-plated steel ribbons are tamped with the active material consisting of alternate layers of nickel oxide and nickel or graphite flakes. These tubes are then clamped to a punched steel grid under pressure. For the negative plate a nickel plated steel punching having a series of parallel openings is used for the grid. To this are fitted perforated nickel-plated steel pockets filled with the active material. The pockets are fixed in the grid by pressure. Groups of positive and negative plates are made by fitting them to respective connecting rods which pass through holes at the top of the tubes, and are separated from each other by means of washers on these rods. Groups of plates so made are then intermeshed with hard rubber separators to form a cell, and cells are inserted into steel containers, and lids are welded. Pole pieces, where they project through the lid, are insulated. The electrolyte is filled through a filler cap on the lid and several cycles of charge and discharge are given to stabilize the electro-chemical characteristics of the battery.

Battery manufacture started in India in '33, and prior to the outbreak of the War, only one or two firms were in production. Owing to the impetus given by the War, there are now five major concerns, in addition to a number of smaller ones, located in Calcutta and Bombay. The large manufacturers are : the Amco Ltd., Bangalore ; the Standard Batteries Ltd., Bombay ; Estrella Batteries Ltd., Bombay ; the Bharat Battery Manufacturing Co., Calcutta, and the Chloride Electrical Storage Co., Calcutta. During the War, their factories were working under the statutory control of the Government. Only portable pasted type of lead-acid batteries are manufactured in India. Amco Ltd. also produce some types of battery plates, required for train lighting cells. Alkaline batteries are not manufactured.

The quality of Indian batteries is quite comparable with that of imported ones. About 90 per cent. of Indian production consists of motor car batteries. The pre-war production was about 36,000 batteries. In '44, it increased to 122,000 due to heavy demand for defence purposes. The present output is about 36·48 thousand batteries per year. Indian requirements have been estimated at 75,000 units, and the post-War 5-year target has been fixed at 100-125 thousand batteries per year (Rep. Heavy Chem. & Electro-Chem. Industr. Panels, *loc. cit.*, 49).

AVERAGE ANNUAL IMPORTS OF ACCUMULATORS (INCLUDING PARTS) INTO INDIA

	Lakhs of Rs.
In quinquennium ending '33-34	14.07
,, ,, '38-39	6.97
,, ,, '43-44	7.85
In '44-45	13.81
,, '45-46	12.07

The pre-war annual imports mostly from the U. K. corresponded to about 40,000-50,000 batteries at Rs. 16-20 per battery. In addition to these, number of batteries are imported as standard equipment of chassis of motor cars, cycles, and lorries, estimated at 22,000-25,000 batteries per year (Rep. Heavy Chem. & Electro-Chem. Industr. Panels, *loc. cit.*, 50).

EXPORTS OF ACCUMULATORS FROM THE U. K. AND THE U. S. A. INTO INDIA

(No. and val. in thousands)

	U.K.*		U. S. A.**	
	No.	£	No.	$
In '39	43	42	37	171
,, '40	83	91	34	137
,, '41	78	109	47	232
,, '42	42	82	..	..
,, '43	45	88	5	22
			52 †	239
,, '44	85	134	10	54
			202 †	1037

* *Tr. U. K.*, III.
** *For. Comm. & Navig. U. S.* listed as storage batteries).
† Lease-lend.

BEARING MATERIALS

Bearings are used to provide rotating or sliding contact between surfaces to reduce friction. A great variety of materials are used for bearings, the most important of which are bearing metals used in machines. Wood, glass, plastics and other materials are employed to meet special requirements.

A bearing metal should have low coefficient of friction, high compressive strength at working temperature, good wearing qualities, and sufficient plasticity to compensate for minute irregularities in the bearing or shaft. It should be able to carry the weight of the shaft, and sudden load fluctuations without flowing out or cracking (Corse, Bearing Metals and Bearings, 1930, 14).

There are two main types of bearing metals: anti-friction or white metals and bearing bronzes. The former are used as thin linings on bearing shells and are specially suited to light loads at high speed and pressure, and the latter, for cast bearings which have to withstand high pressure and temperature, and for bearing shells.

Anti-friction alloys generally contain lead, tin, antimony and copper. Their structure consists of hard grains in a relatively softer matrix. The grains resist wear and take the load, while the matrix allows an adjustment for avoiding local pressures. There are two main types of anti-friction alloys *viz.*, the lead-base and the tin-base alloys. In the former, the matrix is mainly an alloy of lead, and in the latter, of tin.

Lead-base alloys are comparatively soft and are used for low pressures and slower speeds, as in railway and tramway bearings. In these alloys, antimony increases tensile strength, and hardens lead. When present in more than 13.5 per cent., it tends to increase the brittleness of the alloy, but this can be overcome by the addition of tin, which makes it tougher. An alloy containing 13 per cent. antimony and 15 per cent. tin has the best mechanical properties. Copper, in small amounts, hardens and strengthens the alloy, and prevents segregation. Nickel is occasionally added in very small amounts to improve wearing qualities.

Tin-base bearing metals, also called Babbitt's metals or Babbitts, are superior to lead-base alloys in strength and hardness. They are used for light loads and high speeds and for pressures considerably above the normal, as in automobile, aero- and diesel engine main bearings. These are light and have low fluidity, but are expensive.

Some anti-friction metals for use in automobile pistons contain high proportions of zinc or aluminium alloys.

Bearing bronzes are mainly copper-tin alloys containing *ca.*, 10-12 per cent. tin. These comprise phosphor bronzes (Cu-Sn-P), gun-metals (Cu-Sn-Zn), and leaded bronzes (Cu-Sn-Pb), and contain hard particles of tin-copper in a softer matrix. The copper-tin alloys are used only for cast bearings. Another bearing bronze which is a comparatively recent development is the copper-lead alloy, also known as ' lead bronze.' This consists of soft particles of lead in a hard matrix of tin bronze alloy (Corse, *loc. cit.*, 22) and is used for thin castings on steel shells.

Phosphor bronzes generally contain 10-12 per cent. tin with a small percentage of phosphorus. Phosphorus increases the hardness and tensile strength and the fatigue range of bronzes. It also acts as a deoxidizer and improves their casting qualities. These alloys can stand heavy loads and high pressures, and are preferred to gun-metal for gears, slide valves and journal bearings, on account of their superior bearing qualities.

Gun-metal, containing 2-6 per cent. zinc, has good casting qualities and sufficient bearing properties, and is used mainly in complicated castings for railways, shipbuilding, motor, and all other engineering industries. Zinc slightly improves casting properties and acts as a deoxidizer but does not appreciably affect its mechanical properties, such as strength and impact resistance. The most commonly employed zinc bronze is Admiralty gun-metal (Cu, 88 ; Sn, 10 ; Zn, 2). In Admiralty gun-metal tin may be replaced to a certain extent, by twice its weight of zinc without altering its general properties ; these alloys are known as modified gun-metals and are considerably cheaper. A common modified gun-metal used in this country consists of 85 per cent. copper, 5 per cent. tin, 5 per cent. zinc and 5 per cent. lead, but it is not satisfactory owing to reduction in the difference in hardness between the matrix and the hard particles on account of the increased use of zinc.

Leaded bronzes containing up to 12 per cent. lead, possess increased plasticity due to the presence of small particles of lead, good anti-friction qualities, and superior wearing qualities (Copper Develop. Assocn., Bearing Bronzes, 1935, 9). These are used for bearings in which lubrication is not very good, *i.e.*, in cases where there may be temporary failure in the supply of oil. In such cases lead particles lessen the danger of damage to the shaft.

Lead bronzes containing about 25-30 per cent. lead, and a small amount of tin (up to 1%) have low co-efficient of friction, high thermal conductivity, and high resistance to wear. These are used in place of white metals for higher speeds and heavier loads, as in high-duty aeroplane, automobile and diesel engine crank-shaft bearings, etc. Their plasticity about the shaft is inferior to that of white metals, and special technique is required for casting these alloys into bearing shells.

Graphite, owing to its lower co-efficient of friction, is sometimes mixed with bronzes and anti-friction metals to form ' graphite-bearing metals.' Owing to their porosity, they absorb lubricants and these alloys are used in closed machines. Typical compositions are : (*a*) Cu, 85.5-90.5 ; Sn, 9.5-10.5 ; graphite, 1.5 per cent. max. ; (*b*) Cu, 60-66 ; Pb, 25-33 ; Sn, 6-9 per cent.

Close-grained cast iron with low silicon and maximum carbon content is used as a bearing metal with hardened steel. It wears like bronzes and can stand occasional failure of lubrication due to its graphite content. Glazed cast iron is used for soft iron and steel shafts. Owing to very rapid wear, it has to be changed the moment it begins to cut.

Wood is one of the oldest bearing materials and is still used mainly for large, low-pressure and slow-speed bearings. Only the hardest wood is used, the best wood being *lignum vitae* obtained from *Guaiacum officinale* Linn. and *G. sanctum* Linn. of Central America. During the War, *Acacia sundra* was used as a substitute in propeller tail-bearings. *Mimusops littoralis* (Andaman bullet wood) has been found to be a fairly suitable substitute (Trotter, 1944, 195; 1940, 171).

Recently, laminated fabric-based moulded phenolic plastics and some kinds of nylon are being used as bearings for low load-speed ratios, and moulded glass for bearings when electrical insulation is required.

A number of gem stones, e.g. inferior types of ruby, and corundum and garnet are used for pivot supports in delicate instruments, as jewel bearings of watches, and for bearings in scientific instruments. Steel is also used in bearings for cheap watches.

Prior to World War II, the Indian demand for bearing metals was mainly met by imports. The Railways, who are the biggest consumers, also produce some for their own use by refining non-ferrous scrap. Since the outbreak of War, imports rapidly declined and production has been undertaken by several Indian firms, who refine scrap with small quantities of virgin metals. Their products are considered to be equal to the imported alloys.

In the manufacture of anti-friction metals, the ingredient with the highest melting point is first melted in cast iron pots, and the others are then added in the decreasing order of their melting points. In the case of bronzes, a master alloy of copper and antimony or copper and tin is made, which is later employed according to requirement. Bronze is made in graphite crucibles. Prior to pouring into moulds, the melt is deoxidized by the addition of phosphor-copper or phosphor-tin alloy, an extra amount being needed for producing phosphor-bronze.

The approximate annual production by Indian Railways is 500 tons of anti-friction metals, and 5,000 tons of bearing bronzes (Indian Ry. Bd.).

AVERAGE ANNUAL IMPORTS OF ANTI-FRICTION METALS

	Cwt.	Rs.
In quinquennium ending '33-34	4,596	2,69,754
,, ,, '38-39	2,624	2,29,773
,, ,, '43-44	1,205	4,78,948
In '44-45	144	35,565
,, '45-46	350	80,473

During the quinquennium ending '38-39, U. K. supplied about 95 per cent. of the total imports. Imports are subject to a revenue duty of 30 per cent. *ad valorem.*

BEARING MATERIALS

WHITE METALS MANUFACTURED IN INDIA

Description	Composition (per cent.)				Melting and pouring temperature	Applications	Price per cwt (July, 1947)
	Sn	Sb	Pb	Cu			Rs. a.
*No. 6 & †I. R. S. Cass III	5.5-6.5	12-14	77-80.5	1-1.5	310-340	Ry. carriage and wagon bearings; ordinary bearings in gins, oil and sugar crushers.	105 0
*No. 10 ..	10	15	74	1	320-340	Light combustion engines.	133 0
†I. R. S. Class II	13-15	10-12	72-76	..	..	Metallic packing for piston and valve rods.	..
*No. 20 ..	20	19	60	1	300-340	Crude oil and kerosene motor engines.	164 8
*No. 42 ..	42	10	47	1	300-350	Heavy bearings. ..	234 8
*No. 60 & † I. R. S. Class I	58-60	11-13	19.5-24.5	5.5-6.5	300-340	Locomotive and heavy steam engine bearings.	322 0
†I. R. S. Class IV	79.5-83.5	9-11	2-3	5-6	..	Motor and high-speed engine bearings.	..
†I. R. S. Class V	82-85	10-12	..	5-6	..	Locomotive axle-box & connecting rod big end bearings.	..
*No. 83	83	11	..	6	400-420	Heaviest bearings. ..	385 0
*No. 90 ..	90	6.5	..	3.5	300-400	Steam and water-turbines, diesel and high class motor car engines.	406 0

*The number denotes the percentage of tin.

†Brinell hardness of I.R.S. (Indian Ry. Standard) anti-friction alloys ranges from 23-32.

BEARING BRONZES MANUFACTURED IN INDIA

Description	Compositon (per cent.)						Prices per cwt. (July, 1947)
	Sn	Cu	Pb	Zn	P	Uses	Rs. a.
Phosphor-bronze (I. R. S. Class I)	10-12	86.4-88.6	..	..	0.4-0.6	For heavily loaded bearings.	130 0
Gunmetal (I. R. S. Class II)	9-11	88-90	..	2-3	..	Axle-box bearings, connecting rod large end bearings, tender bearings, etc.	..
Gunmetal Grade I	5	85	5	5	..	....	130 0
Gunmetal Grade II	5	80	5	10	..	....	111 8
Leaded bronze (I. R. S. Class III)	8-10	73-77	14-16	..	..	Carriage and wagon bearings, steel and non-ferrous axle-box bearings.	..
Leaded bronze (I. R. S. Class IV)	9-11	78-82	9-11	..	..	Connecting rod bearings, and side rod and motion bushes.	..

BEER AND BREWERIES

Beer is an alcoholic beverage produced by the fermentation of malted barley. Although the preparation of fermented beverages has been practised in India since early times, the art of brewing beer does not appear to have existed before the advent of Europeans. The first brewery was started in Murree in 1860. Sinee then several others have been established in different parts of the country. At present there are four European managed firms who are controlling most of the important breweries in India.

BREWERIES IN INDIA

	Location	Annual production capacity (1000 gal.)
Dyer Meakin Breweries Co.	Solan Lucknow Kasauli Ranikhet	10,80
Murree Brewery Co.	Rawalpindi	14,40
United Breweries Co.	Bangalore Kaity (Nilgiris) Madras	15,00
Bengal Breweries Co.	Calcutta	1,80
	Total ..	42,00

The two principal operations involved in the production of beer, malting and fermentation, require a comparatively cold climate. The first breweries were, therefore, located on the hills in India, and even now, most of the malting is done on the hills.

Barley suitable for malting should be of bright yellow colour, free from other food grains and dirt, and should germinate readily. Besides, the grains should be mature, well filled, plump and uniform, with a comparatively low protein content (8-10 per cent), and when cut they should show a chalky appearance. 1,000 grains of good malting barley should weigh not less than 30 g., a wt. of 50 g. per 1,000 grains being considered excellent.

There are two main classes of barley, the two-rowed class (*Hordium distichon*), and the six-rowed class (*H. vulgare*). The former is suitable for malting, and is used in Europe. Indian barley belongs to the latter class and is generally unsuitable. However, barely grown in some of the south-eastern districts of the Punjab (Gurgaon, Ferozepore and Pataudi State), and in certain districts of the U. P. (Bulandshahr, Agra, Muttra and Hardoi) has been found suitable for malting (Rep. Marketing Barley India, 1945, 9 ; *vide* also *Dep. Agric., U. P., Bull.* No. 43, 1944, 2).

COMPOSITION OF BARLEY

(Per cent.)

	Water	Protein	Fat	Starch	Fibre	Ash
*English	14.3	10.6	2.1	66.0	4.5	2.5
*German (medium ground)	14.3	9.4	2.1	67.8	3.9	2.5
*American (Wiley)	10.9	11.0	2.3	69.6	3.9	2.5
†Indian	12.5	11.5	1.3	69.3	3.9	1.5

* Bacharach and Rendle, The Nation's Food, 1946, 201.
† *Hlth. Bull.* No. 23, 1941, 26.

BARLEY CONSUMED BY INDIAN BREWERIES *

(Tons)

Name	'36-37/'38-39 (annual av.)	'39-40	'40-41	'41-42
Murree Brewery Co. ..	510	739	2,204	2,167
Dyer Meakin Breweries Co.	833	910	1,229	1,836
United Breweries Co. ..	331	371	495	693
Total ..	1,674	2,020	3,928	4,701

*Rep. Marketing Barley India, *loc. cit.*, 54.

Rice, wheat or maize are the usual malt adjuncts. These should be fully mature, and free from extraneous matter. Sometimes sugar or *gur* is also added to help in the clarification of beer and to increase its sweetness. Both barley and the malt adjuncts, used in brewing, should be completely free from fungus or insect attack.

Hops, which are added to impart flavour and to provide antiseptic matter to beer, consist of the female inflorescence of *Humulus lupulus*, cultivated in England, Europe and America. It has been introduced into Kashmir and Chamba States, but is not cultivated on a large scale in India (*Indian Fmg.*, 1942, **3**, 25). At present, hops are imported (annually about 39 tons valued at Rs. 80,000 during '34-35/'38-39). Hops contain : protein, 12-24 ; bitter resins, 11-20 ; tannin, 2-6 ; essential oil, 0.4-0.8 ; and ash, 5-9 per cent. The essential oil gives the flavour, the resins possess antiseptic properties, and the tannins help to coagulate some proteins.

Yeast used in brewing belongs to the *Saccharomyces* group. These convert maltose and other sugars into CO_2 and alcohol. *S. cerevisiae* Hansen, called ' top yeast,' is used when fermentation is carried out at a higher temperature. During fermentation it is carried to the top of the vats by the rapidly evolving bubbles of CO_2. *S. carlsbergensis* Hansen is the typical ' bottom yeast,' used for slow fermentation at a lower temperature. During fermentation, it settles at the bottom of the vats. The brewers generally use yeast collected from their fermenting vessels. Unless proper care is taken to maintain purity of the yeast used successively, it is gradually contaminated with undesirable proportions of ' wild ' yeast and bacteria. Many modern breweries use pure cultures of special strains.

Suitable water for brewing is of great importance. To make light, clear ale, permanent hard water containing 50-100 gr. of salts should be used. A less hard water may be used for porter and stout. If soft water is used, salts are added in suitable proportions. Phosphates are added, if required, at the wort stage, to supply nourishment to yeast. Carbonates in excess of 1-2 parts of CO_2 per 100,000 parts of water are undesirable. The less of nitrates in water the better, as these tend to weaken yeast. Presence of iron also is undesirable as it affects the colour of beer.

White oak (*Quercus alba*) is the best wood for liquor casks, but is not available in India. *Quercus dilatata*, *Q. semicarpifolia*, *dhaman* (*Grewia tilaefolia*) and *sandan* (*Ougeinia dalbergioides*) are reported to be good substitutes (Trotter, 1940, 163; 1944, 207). These, however, have to be paraffined, or otherwise coated on the interior, as a precaution against leakage. Pressure casks, bottles and crown cork are largely imported.

In the preparation of malt from barley, selected grains are steeped in water in containers having false bottoms for 48-70 hrs., at 50-53° F. Water is run off every 24 hrs. and intermittent aeration is given. The steeped barley is then ' couched ' or spread on the malting floor or a rectangular frame called 'couch' for 12-14 hrs. at 55-60°F. and turned very frequently to maintain uniformity of moisture and temperature, and for proper aeration. The germination and malting is usually completed in 7-8 days. Loss of moisture is replenished by sprinkling water, and uniformity of temperature is maintained by letting in hot or cold air, as required. Lighter barley malts more quickly than heavier varieties. The steeped malt is stacked in heaps for 1-2 days for withering. The withered malt is then dried in a kiln and the moisture content brought down to about 6 per cent. by raising the temperature slowly to 150°F. during 2-3 days. In the next 6-8 hrs. the temperature is raised further (for pale ale, 190-195°F., for mild ale, a little higher, and for porter and stout, 205-215°F.). The dry malt now contains about 2 per cent. moisture and has a biscuit flavour. The activity of diastase and other enzymes, developed during germination, is arrested, and the rootlets wither and drop off.

The dry malt is stored in air-tight containers and should not be allowed to gain more than 4°/₀ of moisture from the atmosphere. During malting, starch in barley is only slightly attacked (5 per cent.), and its conversion into malt-sugar takes place mainly in the next stage.

For mashing, malt is coarsely ground between rollers. Grist and pieces of unmodified grains are sieved off, ground fine, and mixed with ground malt or grist. Two methods of mashing are generally followed: infusion mashing, followed in England and also in India and decoction mashing, practised in larger breweries. Infusion mashing consists in adding water at 158°F. to grist (2-3 parts to 1 part of grist), and mixing the two in a hopper to the consistency of porridge. Maize, rice or other grains, used as malt adjuncts, are first washed, their starch gelatinized in a steam-heated converter, and then added to malt grist. Invert sugar, glucose or raw crystal sugar, if desired, is also added at this stage.

The mixed grist is then passed into the mash tun, a cylindrical vessel with a false bottom of perforated metal plate. It may be of wood, lined with copper, or of iron or aluminium. The period of infusion in the mash tun is generally 2 hrs. and the temperature is maintained at 150°F. Under English conditions of mashing, more nitrogen is brought into solution and starch is converted into maltose (55-65 per cent.), glucose and other sugars (12-15 per cent.), and dextrins (20-30 per cent.). By regulating the condition of mashing, the proportion between maltose and dextrins can be varied to suit the requirements of the kind of beer to be brewed. For strong beer with little body, or beer not to be stored or exported, more of maltose and less of dextrins are needed, but for beer to be exported, or for stout, more of dextrin is necessary to keep it sparkling and to prevent it from turning acid.

The liquor or 'sweet wort' is drawn off through perforations in the false bottom of the mash tun. The residue is 'sparged' or washed with hot water (176°F.) sprayed on them. In certain breweries the whole mash is passed through a filter press. This enables the use of finely ground malt and grain.

The wort is then boiled with hops for 2-3 hrs. in the 'coppers' or copper vessels fitted with steam jacket or closed steam pipes. This boiling destroys the enzymes, and sterilizes the wort. The essential oil and the bitter resins of hops are extracted, and the proteins coagulated. In some cases, hops are added in lots, the last portion being added half an hour after boiling is complete.

The spent hops and the coagulated proteins are quickly separated, and the clear bright wort is cooled and allowed to stand for some time (30-60 min.) when some sludge is deposited. It is then passed on to the refrigerators, which consist of flat copper pipes through which cold water or brine flows, and thence to the fermenting vats. The rate of flow is regulated according to the temperature at which wort is to be fermented. For top-fermentation it enters the fermenting vessel at 58-61°F. and for bottom fermentation (lager beer) it is cooled to 40-41°F.

The fermenting vessels are made of wood, or wood lined with copper. Vessels of stainless steel, cement or stone are also used. In the Rawalpindi brewery, jacketed aluminium vessels are used. Cold water or brine flows through the jacket to keep the temperature low. Other types are fitted with cold water pipes or 'attemperators.' After the vessels have been filled, and the density of the wort adjusted by mixing with weaker wort or washings, it is impregnated with yeast.

The quantity of the yeast to be used depends upon the strength and kind of beer desired. In Europe 1 lb. of pressed yeast per barrel of 36 gal. is usual. In India 1.5-2.0 lb. of good thick stiff yeast are added per barrel of 36 gal. of wort (*d*, *ca.* 1.055). For wort of higher density (1.066) to which a larger quantity of hops has been added, 2.5-3.5 lb. of yeast per barrel are required.

In top fermentation, fermentation becomes fairly vigorous, within 4 hrs. of impregnation, and is usually complete within two days. The temperature is not allowed to rise above 55-60°F. by attemperators. Yeast rises to the top and flocculates forming a firm spongy mass. This is skimmed off and preserved for future use. The products of alcoholic fermentation are about 51 per cent. of alcohol, 49 per cent. of CO_2, 2 per cent. of glycerol, with small quantities of organic acids, higher alcohols, etc. Acidity increases and the pH falls from 5 to 4.

In bottom fermentation, as for the preparation of lager, the wort after impregnation with yeast is kept at a temperature of 41°F. for 24 hrs., 'the dead period.' It is then transferred to fermenting vessels, and fermentation is allowed to proceed more briskly at about 56°F. It is complete after about 7-10 days and yeast settles at the bottom of the vats.

After fermentation is complete, beer is allowed to stand for about two days, when some more yeast settles down. It is then run off (raked) either into storage vats or casks for maturing, or is bottled for immediate issue. Some breweries, like the Murree Brewery, collect CO_2 produced during fermentation, and use it for carbonating storage beer. After raking or removal from storage vats, beer is filtered. Lager is low in alcohol and contains a higher percentage of extract.

In the older 'krausing' process, beer is matured and carbonated by storing it in a cellar at 32-36°F. for 2-4 weeks. It is then transferred to pressure vessels, and mixed with 12-15 per cent. of its volume of beer in the first stage of fermentation. Slow fermentation continues and beer gets charged with CO_2. Carbonation is allowed to continue for 2-4 weeks till the concentration of CO_2 reaches 0.45-0.52 per cent. (by wt.). This is then stored for another 3-4 weeks.

In the modern carbonating process, beer is allowed to ferment to completion and to settle for some time. It is then pumped into a storage cellar, cooled to 32°F. and stored 3-6 weeks, for settling and mellowing. After filtering, carbon dioxide is passed in until 2.7 vols. of gas are absorbed (von Loesecke, 421).

In some cases, specially when beer is to be consumed before sufficient time is allowed for clarification, 'finings' are added, at the rate of 1-2 pints per barrel. The finings usually consist of a solution of isinglass (*ca.* 3 lb. in a barrel). 'Dry hopping,' the addition of one half to one lb. of hops of the finest quality to a barrel of beer at the time of raking, enhances its flavour and keeping qualities, and also clarifies it. Sometimes beer is pasteurized after bottling, the bottles being heated by immersion in hot water at 136-144°F., for about three-quarters of an hour.

Beer is considered to be more a food supplement than a stimulant. Its alcoholic content is low (4-5 per cent.), and it contains some nutrients in the form of dextrins, sugars (3.1-4.9 g./100 c. c.) and digested proteins (0.2-0.5 g./100 c. c.). The hops resins present in it stimulate appetite and indirectly aid digestion. It is for these reasons that beer is more lightly taxed than other alcoholic beverages.

Variations in the quality of beer (strength of alcohol and the quantity and nature of extractives) depend on the quantity of malt and malt adjuncts used for the preparation of wort, the amount of hops added, and on the conditions of fermentation. The alcoholic strength of the usual types of beer, produced in India, does not exceed 7.5 per cent. by vol. corresponding to a sp. gr. of 1.065 of the wort. In south India a cheaper beer, called Tavern ale or Government beer, is produced, and the Excise Dep. controls the quantities of malt and hops used (Bedford, Tech. Excise Manual, 1916, 110 & 116).

COMPOSITION OF BEER AND ALLIED FERMENTED BEVERAGES

	Alcohol (C.c./100 c.c.)	Total solids (G./100 c.c.)
1. Mild ale	4.5	3.3
2. Strong ale	8.0	5.3
3. Lager (English)	4.6	4.9
4. Porter	5-6	..
5. Stout	7-8	..
6. Pale ale (Indian)	5-8	..
7. 'Tavern ale'	8-11	..
8. Toddy (Palm)	4-5	..

1 & 2, McCance and Widdowson, 96 ; 3, Thorpe, II, 105 ; 4 - 8, Bedford, *loc-cit.*, 6 & 7.

Carbon dioxide is the principal by-product of the brewery industry. It is generally collected, compressed into cylinders and sold to manufacturers of aerated waters.

Among the waste products, brewers' grains, the residue left after extraction of malt, when fresh, are used for feeding cattle. They contain over 70 per cent. of moisture and hence deteriorate easily. When unfit for stock-feed, they are used as fertilizer. Dried brewers' grains are more suitable for feeding animals. They contain : water, 10.3 ; protein, 18.3 ; fat, 6.4 ; soluble carbohydrates, 45.9 ; fibre, 15.2 ; and ash, 3.9 per cent. (*Bull. Minist. Agric., Lond.*, No. 124, 1945, 15). Barley sprouts, which are separated from germinated grains during drying, are also used as feed for live-stock. If they deteriorate, they can be ground to powder and used as fertilizer. Their average composition is : nitrogen, 4-5 ; phosphorus pentoxide, 1-2 ; and potash, 2-2.5 per cent. Hop residues are also used as fertilizer for light soils, preferably after composting (Bruttini, 234). Dried brewers' yeast is a rich source of vitamins of the B group. It contains : proteins, 46.1 ; carbohydrates other than fibre, 36.6 ; fat, 1.6 ; phosphorus, 1.89 per cent., and vitamin B_1, 14,000 ; vitamin B_2, 5,000 **u** (**g**) and nicotinic acid, 50 mg. per 100 g. (Heinz & Co., Nutrit. Charts, 1942, 29).

During the War, it is estimated that the breweries paid Rs. 9 per md. of cleaned barley and that the cost of production of malt was Rs. 15 per maund. Hops used to cost Rs. 3-1-0 per lb. On the basis of these prices the Government was purchasing beer for supply to the Services at Rs. 7-2-0 (inclusive of overhead charges and excise duty) per doz. quart bottles.

INDIAN PRODUCTION OF BEER

(In 1,000 gal.)

	Indian Beer	Beer brewed on English principles	Stout	Total
'38-39 ..	357	752	38	1,147
'39-40 ..	397	846	68	1,311
'40-41 ..	437	1,377	75	1,889
'41-42 ..	1,876	1,486	107	3,469
'42-43 ..	1,672	1,874	63	3,609
'43-44 ..	1,581	1,731	120	3,332
'44-45 ..	1,869	1,759	8	3,636

BEER AND BREWERIES

Production of beer in India has shown a continuous decline in the period between the two World Wars. Production in '18 was 8.2 million gal. (*Statist. Abstr. Br. India*, '17-18/'26-27, 641), while in '38-39 it was only 1.2 million gal. (Punjab, 860,000 gal.; Madras, 195,000 gal.; and Bengal, 155,000 gal.). Imported beer, although more expensive, was in greater demand because of its superior quality. During the last War, production again increased and rose almost up to the max. capacity of Indian breweries, owing to stoppage of imports, and heavy demand from Defence Services.

EXCISE REVENUE FROM MALT LIQUORS
(In lakhs of Rs.)

	'38-39	'44-45
Punjab	5·5	18.5
Bengal	2.6	6.1
U. P.	1.2	3·5
Madras	4.1	6.2
The rest of British India ..	1.3	5·3
Total for British India ..	14.7	39.6

The excise duty on bulk beer, per gal., varies from As. 8 in Bihar and Orissa, to Re. 1 in Baluchistan and C. P., and on bottled beer, from Re. 1 in Bombay to Rs. 1-12 in Sind, per doz. quart bottles.

During the quinquennium ending '38-39, bottled beer formed the largest proportion of imports (66 per cent.), the chief suppliers being the U. K. (57 per cent.); Japan (15 per cent.); Netherlands (15 per cent.); and Germany (11 per cent.). Since the commencement of World War II, imports have declined continuously. Customs revenue from imports of ale, beer, porter, cider and other fermented liquors was Rs. 36.1 lakhs in '38-39 and it dwindled to Rs. 3.1 lakhs in '43-44. Import duty is now (1947) charged at the rate of 3 annas per bottle of 20-27 oz. capacity, Rs. 1-2-0 per Imp. gal. in barrels (above 27 oz.), and Rs. 1-8-0 per Imp. gal. in other containers.

During World War II, some Indian breweries greatly improved the quality of their products, and if this improvement is effected in others also, the Indian industry will be able to meet the entire demand of the country.

AVERAGE ANNUAL IMPORTS OF BEER INTO BRITISH INDIA
(Qty. and val. in thousands)

	Ale and beer		Stout and Porter		Total	
	Gal.	Rs.	Gal.	Rs.	Gal.	Rs.
In quinquennium ending:						
„ '33-34	39,23	81,48	1,51	5,43	40,74	86,91
„ '38-39	36,20	71,59	1,01	3,55	37,22	75,14
„ '43-44	18,79	50,04	81	3,47	19,60	53,51
In '44-45	4,20	14,27	..	..	4,20	14,27
„ '45-46	1,43	5,84	..	..	1,43	5,84

BELTING

Belting is extensively used for transmission of power from prime-movers or from shafts to machines in all industries and workshops. It is also used for conveyor and elevator belts. The principal types are cotton (solid-woven), hair, leather and canvas-ply.

The first belting factory in India was started in 1882, when Birkmyre Brothers, Calcutta, commenced manufacturing cotton belting from imported cotton. In 1904, they started making their belting from imported hair and cotton yarns. The Bengal Belting Works (Serampore, Hooghly dist.) was founded in 1926. There are at present two more firms in the Serampore area, manufacturing solid-woven cotton and hair beltings.

India manufactures adequate quantities of hair belting. It is used in cotton and jute mills, railway workshops, mines, saw mills, rice mills, cement, match, sugar, oil and paper factories, and for all other drives requiring superior quality belting. It has high elasticity and will remain soft and pliable during its whole life. Canvas-ply beltings may be plain, rubberized, bitumenized or treated with balata. Bitumenized beltings are generally used in workshops, and rubberized beltings for train lighting dynamos. Plain canvas-ply belting is used for light drives and as conveyor or elevator belting, and is manufactured in small quantities.

Rubber beltings are not manufactured in India. They have high tensile strength, good grip and resistance to deterioration by moisture, and are sufficiently strong to hold metal fasteners. Balata belting also is not made in India. It is similar to rubberized and bitumenized belting, and is also waterproof. Balata belting is not elastic, does not age, and is not affected by oil.

A fair amount of leather belting is also produced especially in Chromepet (S. India), Bombay and Calcutta, and also in Cawnpore, Jullundur and Bangalore. But the products are of inferior quality.

Yarn of 10^s, 12^s, 15^s, or 16^s count, spun from indigenous long staple cotton, is used in the manufacture of cotton belting. It is also used as weft, and as binders for inter-stitching plies, in the manufacture of hair belting. Cotton or flax canvas is used for the manufacture of all types of canvas-ply beltings.

For hair beltings, a variety of worsted yarn made from all kinds of long coarse hair, is imported from England. The hair is twisted into 5^s count yarn of 3-4 plies.

The manufacture of solid-woven beltings is similar to that of cotton piece-goods or of hessian cloth, except that more plies of warp, generally 3-5, are used. The yarn from hanks is cheesed, multiplied, twisted and bleached for being used as warp. Similarly weft yarn is light-twisted and wound over pirns. Weaving is done on special multiple fabric looms. The several layers of warp, of twisted hair or cotton yarn, are woven with cotton weft under tensile stress into a solid and homogeneous belting, and in the same operation the plies are inter-stitched using cotton yarn binders. In hair belting, the hair warp gives the traction and takes the load pull, while the cotton weft, which binds the several layers of the warp, controls the stretch on hair, and strengthens the belting. The woven belting is treated with a dressing composition, like red oxide in linseed oil mixed with a little terebine. The dressing colours the belting, preserves the fabric, and lubricates it. The belting is then stretched, calendered and rolled.

Canvas-ply beltings are not of the solid woven type. For their manufacture, canvas or duck is folded into the requisite number of plies, and stitched together. These are then treated with a dressing composition, stretched, calendered and rolled. They are made in 4, 6, 8 and 10 plies.

Rubberized belting is made from cotton-ply belting by impregnating the surface with a latex compound and vulcanizing it. Bitumenizing is done by putting the belting into a tank containing bitumen or pitch, and allowing it to soak for 1 or 2 days.

For high quality leather belting, the leather should be cut from the butt. Such leather is uniform, and has minimum stretch and maximum elasticity. It produces belts which will run straight and quiet on the pulley. Sometimes shoulder and belly portions are also used, but they yield inferior products. Tanning is done by the pit tanning process similar to that used for sole and harness leather. The leather is curried to bring it to the pliable condition essential for durability, good adhesion, and elasticity. It is then painted on the grain side and rolled to make it smooth and straight.

Ox-butt yields the best belting. Strong hides, free from grain faults, sores, scratches, warble holes and butcher cuts, are selected. In India, buffalo leather is used, but it is less firm in structure. The leather is cut into strips of required width, passed through a rolling machine and compressed, or alternatively compressed before cutting. The cut lengths are then matched for uniformity of texture and thickness, the ends spliced or bevelled, and joined by glue, stitching, riveting, etc. In India, the joints are made by stitching with raw cow-hide laces, or with imported leather cements. The stitched belting is passed through a pair of rolls, to compress the leather and to smoothen the joints. It is then coiled into tight rolls, and finished to the correct width by scraping the sides with tools and glass edges, and coloured on the surface. The outer ply of leather beltings is dressed with wax, tallow, oil or grease.

Leather belting may be made of one or more plies according to the strength and drive required, but generally only single ply beltings and small quantities of double-ply beltings are manufactured. Common leather beltings are not durable when exposed to steam, dampness or oil. Special waterproof leather beltings are made for use under conditions of excessive moisture. The consumption of leather belting in India is large, but the demand is reported to be decreasing.

The two ends of a belting are generally fixed together by means of fasteners, metal clips, rivets, etc. The types commonly used are Alligator and Walker fasteners, of which the former is manufactured in the country.

The pre-war capacity for the production of cotton and hair beltings was approximately 750 tons per annum. The present capacity of the four concerns engaged in this line is 1,600 tons per annum, while the output is about 850 tons per annum. The capacity for leather belting is about 650 tons per annum. Indigenous textile beltings are as good as imported ones, but Indian leather beltings are considered to be inferior to imported ones made from ox-hide.

IMPORTS OF BELTING INTO INDIA
(Tons)

Types	1944	1945
Cotton belting	252	150
Hair Belting	594	390
Leather belting	649	623
Rubber belting	406	764

*Minist. Industry & Supply.

U. K. supplied 65 per cent. of the imdorts during the quinquennium ending '38-39.

Imports of cotton, canvas-ply and hair belting are subject to a revenue duty of 7½ per cent. *ad valorem.* Other varieties are subject to a revenue duty of 10 per cent. *ad valorem.* Import duty on hair yarn for hair belting is at present 7½ per cent. *ad valorem.*

Small quantities of leather beltings are exported to Burma, Ceylon, Kenya, Malaya, Indo-China and the East Indies.

The demand for belting in India is largely industrial. The other important consumers are the Indian Railways who are stated to use annually about 200 tons. The postwar demand for belting is estimated at 2,000 tons per annum.

VALUE OF AVERAGE ANNUAL IMPORTS OF BELTING

(Lakhs of Rs.)

	Cotton	Hair	Leather	Other materials including coir	Total
In quinquennium ending :					
„ '33-34	7.95	..	28.67	23.95	60.57
„ '38-39	6.84	10.33*	23.70	14.98	51.71
„ '43-44	6.76	14.48	33.25	12.61	67.10
In '44-45	13.03	23.54	57.29	16.03	109.89
„ '45-46	9.25	25.68	50.64	31.53	116.50

* Av. of 3 years from '36-37.

PRICES OF INDIAN AND IMPORTED BELTING*

(Per foot)

	3"		4"	
	Indian	Imported	Indian	Imported
	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.
Cotton	0 9 0	0 14 2	0 12 0	1 3 0
Hair	1 1 0	1 4 0	1 7 0	1 10 11
Rubberized canvas	0 9 0	..	0 12 3	..

Minist. Industry & Supply, 1947.

BIDIS

Bidi is the cheapest Indian smoke and is made by wrapping tobacco in a specially prepared leaf. The raw materials required are tobacco, wrapper leaves, and cotton thread.

The best and the most extensively used *bidi* tobacco comes from Gujarat and from the Nipani area of Belgaum (Bombay Province). But this tobacco is often mixed with inferior tobacco from Bihar, U. P., Hyderabad and Mysore, and scraps and rejections from Guntur tobacco. The nicotine and ash content are respectively 3 and 19 per cent. in Gujarat leaves, 4 and 19 per cent. in Nipani leaves and 4.9 and 24 per cent. in Mysore leaves (Rep. Marketing Tobacco India and Burma, 1939, 33).

For *bidi*-making, tobacco should be carefully selected. Gujarat tobacco should be light orange-yellow in colour, and the Nipani brand should be greenish. Strong thick leaves are dried and crushed to powder and sieved. *Bidi*-powder is generally packed in gunny bags. Bombay exports large quantities to C.P. & Berar, Rajputana and Central India. Madras also imports some from Bombay, but obtains the bulk (86 per cent.) from Mysore. In making *bidis*, mixtures of tobaccos are generally used, and the mixture used by each manufacturer is kept as a trade secret.

The leaf of *Diospyros melanoxylon* is the most commonly used cover for wrapping *bidis*, especially in Bihar, the C. P., Orissa and Bombay. It is also used to a smaller extent in Madras. Bombay imports it from the C. P. In the U. P., *bidi* leaves (*D. melanoxylon* and *D. tomentosa*) are collected in Bundelkhand division.

Leaves of *Bauhinia racemosa* are also extensively used for wrapping *bidis*, in Bombay and Madras. In Assam, leaves of *Castanoposis indica* are also used. *Butea monosperma* leaves are commonly used in Bengal and to some extent also in Madras.

The best quality *bidi* leaves obtained from *D. melanoxylon* are those plucked just after they have turned from crimson to reddish-green and become leathery in texture. They should be soft and pliable, and should not have an excess of pubescence on the underside, or stiffness of primary and secondary veins (*Indian For. Leafl.* No. 60, 1944, 6).

The leaves are tied together in bundles of 25-150, and exposed to the sun for 5-10 days. They are turned over frequently until completely dried. In some localities, the leaves are first dried in shade and later in the sun. In Bengal, the leaves of *Butea monosperma* are boiled in water before they are dried. *Bidi* leaves are generally packed in gunny bags, and can be stored for about 2 years.

Bidi-making is a simple process. The dried leaves are softened by soaking them in water overnight, and then cut into rectangular pieces about 3″ × 1.5″. The cut leaf is then rolled by hand into a conical form, the tobacco mixture put into it, and the broad end closed by bending it over the wrapper. The other end is then tied with thread. About 10-16 oz. of tobacco are required for 1,000 *bidis*.

The *bidis*, after drying, are tied into bundles of 25 each, wrapped in coloured paper, and labelled. These are made into packets of 500 *bidis* and transported in gunny covered bamboo crates, each containing about 40,000-60,000 *bidis*.

Bidis are generally made in three sizes ; small, medium and big. They are 2″, 2¼″ and 3″ respectively in length. The quality depends on the wrapper leaves, and the tobacco. Good *bidis* must be properly rolled. *Bidis* of medium strength and size, made out of bright yellow wrapper leaves, packed fully with tobacco are preferred.

Large-sized *bidis* with strong flavour are liked by the working class.

About 80,000 million *bidis* are made every year in India. *Bidi* industry has developed mainly in places where wrapper leaf is available in plenty, since it is more economical to transport tobacco than the leaf. The C. P. and Berar are the most important centres of the *bidi* industry and about 25 per cent. of the total Indian output is made there, and more than 60 per cent. of this is made in the dist. of Bhandra. Almost three-fifths of the total manufacture in the C. P. is controlled by the big manufacturers in Jubbulpore, Gondia, Nagpur and Kamptee.

Madras and Bombay come next in order of importance, each producing about 20 per cent. of the total Indian manufacture. In the north, Delhi is an important producing centre. In Bengal, Bihar and U. P., the industry is localised in larger towns. *Bidi*-making on a fairly large scale is also prevalent in Mysore and Hyderabad. The industry is not found in the Punjab.

The C. P., which produces the maximum quantity of *bidis*, exports 75 per cent. of its production to other parts of India, and Burma. The wholesale price of *bidis* in the C. P. now(1947), is Rs. 3 to Rs. 4 per thousand. Bihar obtains large quantities from C. P. and Orissa. *Bidis* are also exported to Ceylon and the Maladives.

Bidi consumption is high in Bombay, Sind, Baroda, Hyderabad, and Mysore, moderate in Bengal, Bihar, Orissa, C. P., Madras and Travancore, and low in Assam, N. W. F. P., the Punjab, U. P. and Kashmir (*vide* Rep. Marketing Tobacco India and Burma, *loc. cit.*, 79).

It has been estimated that the *bidi* industry gives employment to about 50,000 labourers in the C. P., and to a lakh in Bombay, and another lakh in South India. In C. P. and Bombay, women and children are also engaged in the industry.

A man can roll on an average, about 1,000 *bidis* per day. The wage rate per 1,000 *bidis* varies from Re. 0-13-6 in Bhandra to Rs. 1-4-0 in Jubbulpore. In Bombay, the rate is Rs. 1-2-0 to Rs. 1-5-0; in Calcutta, it is Rs. 1-9-0 to Rs. 1-14-0 (Lab. Invest. Comm. Rep. *Bidi*, Cigar and Cigarette Industr., 1946, 18).

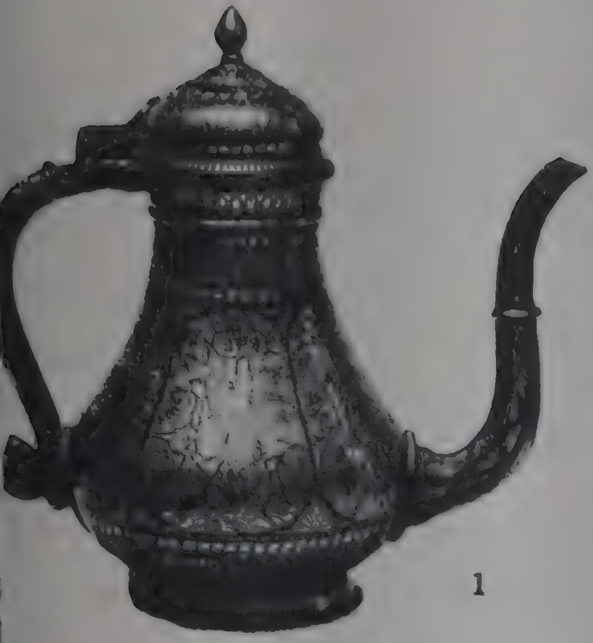
BIDRIWARE

Bidriware was probably introduced into India from Persia in the early twenties of the sixteenth century. It takes its name from Bidar dist. in Hyderabad State, where it is principally produced. Lucknow is the other prominent centre of the industry. Small quantities are also made at Purnea, Murshidabad and Kashmir. In Hyderabad, there has been a notable development recently in the industry, due to the introduction of improved processes and designs (Speight, Bidriware, 1933).

Bidriware is a variety of damascened work in which one metal surface is ornamented by another. The applied metal may be left in relief or sunk into the surface of the base. The base is generally an alloy containing 16 parts of zinc and one part of copper. The small amount of copper gives a better polish to zinc. At Purnea, some lead is also introduced, which makes the pieces heavy. Inlaying is done with silver, and occasionally with gold, on a blackened surface. Copper is rarely used now. Bidriware displays great craftsmanship, and is very appealing because of the contrast between the black base and the inlaid metals, and the richness and variety of designs.

The article to be inlaid is first cast. The matrix is made of red clay over which is applied a layer of wax and resin mixture, the resin being used to give a hardening effect to wax. This is covered by a layer of red clay supported by stops. Wax is melted out and the molten alloy poured in. The rough article so produced is polished with a

Pl. V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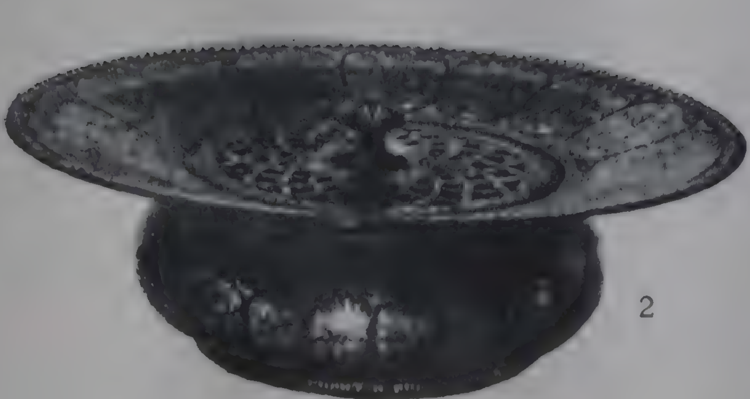
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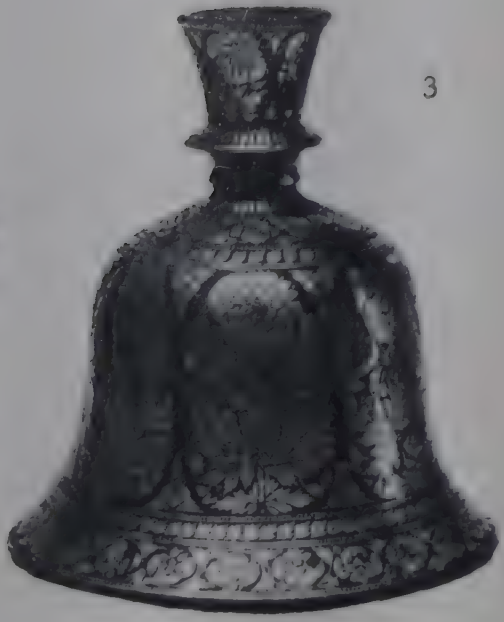
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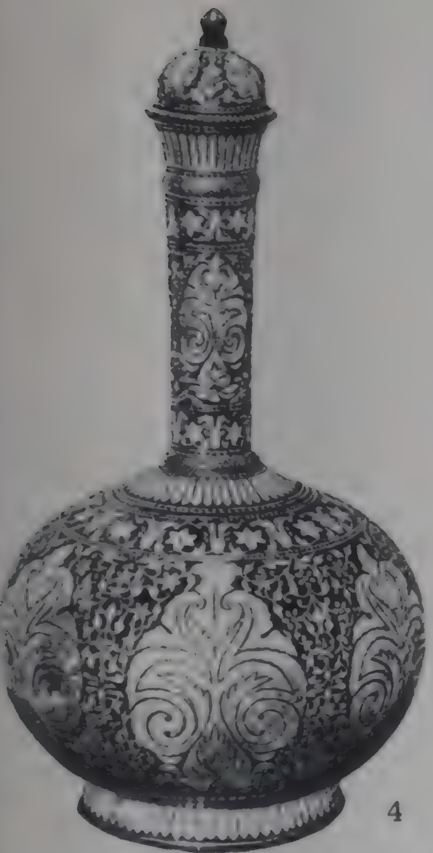
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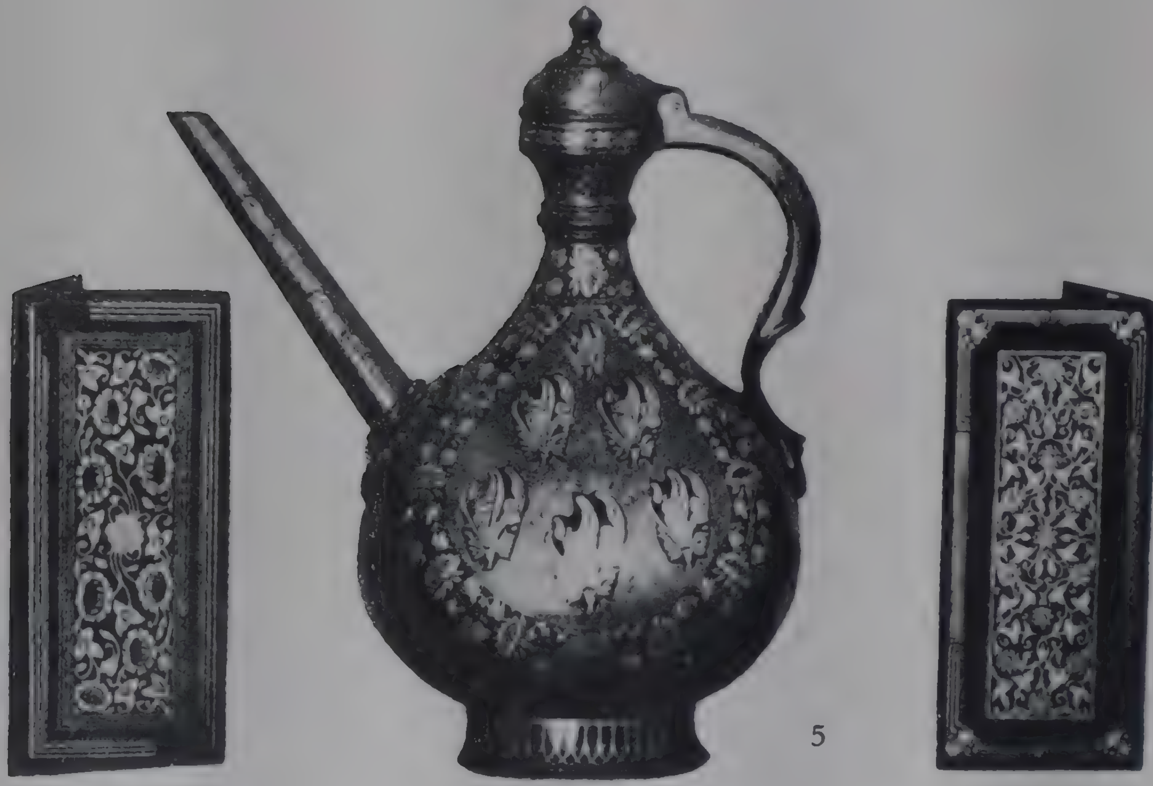
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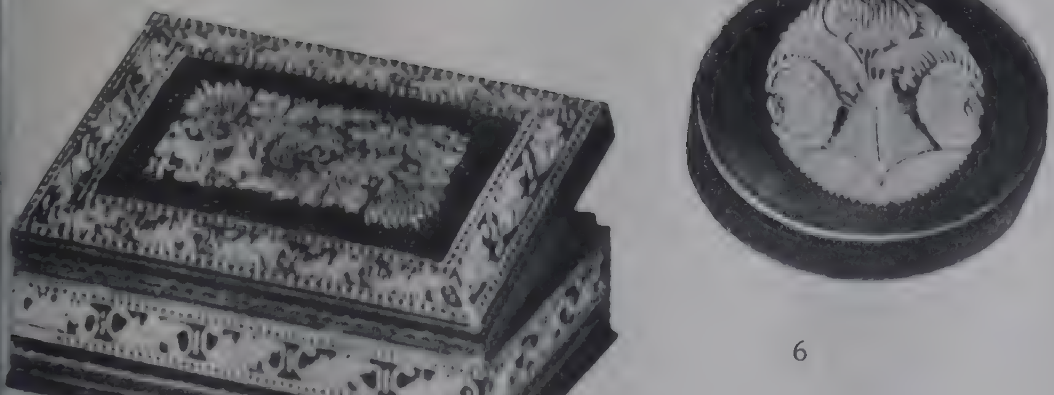
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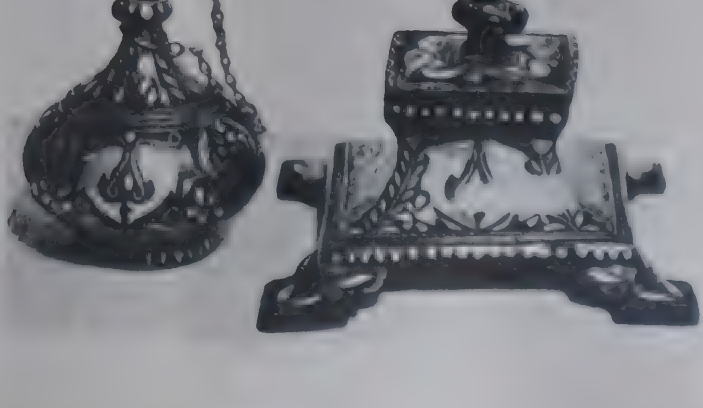
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1, 2 & 3. OLDER TYPES OF BIDRIWARE
4, 5 & 6. MODERN BIDRIWARE
7. LUCKNOW BIDRIWARE

file, or on a lathe, and finished with sandpaper, charcoal, and sweet oil. Blackening is effected by moistening the surface with copper sulphate solution. Designs are then drawn and cut with a fine point and inlaid with silver sheets or wires by hammering. The inlaid articles are filed, polished, and subsequently cleansed with a certain earth found near Bidar.

The inlay workmanship, depending on the place of manufacture, is of three types : *zarnishan* or embossed work, a low relief which can be felt by passing the fingers over the vessel, *tarkashi* or inlay of wire, and *tabnishan* or overlay of sheet silver. The last two types are often found in combination. A special type of bidriware, known as *zarbuland* ware, is also made in Lucknow, in which silver is applied in high relief.

Great ingenuity is shown in the wealth of design of these articles. Floral and geometrical patterns are common. In the best works an attempt is made to reproduce or adapt the beautiful ornamentation of the famous Bidar fort and of the neighbouring tombs.

Leaves, flowers like the poppy and the lotus, and the running vine are some of the common patterns. Mixed with these are to be found arrow-heads, stars, lattice work and trellises. Geometrical patterns like parallel and crossing lines, spots, spirals, are often interwoven with the floral motif. Animal and fish designs are found in Lucknow bidriware. At Purnea, more or less conventional designs, and sometimes, Chinese patterns are used.

Originally bidriware consisted mainly of *hookahs, pandans* (betel boxes), small boxes with trays, water bowls, toys, etc. Some beautiful specimens of antique *bidriware* are found in the Prince of Wales Museum, Bombay, and the Hyderabad Museum, Hyderabad (Deccan). The articles made now are mostly copies, or commercial ware, like cigarette boxes, ash trays, buttons and links, and curios.

BITTERNS

Bitterns are the mother liquors obtained during the manufacture of common salt from sea-water and the waters of saline lakes, and contain all the residual salts.

The sea forms an inexhaustible source of a number of valuable chemicals, some of which are now being prepared directly from it.

AVERAGE COMPOSITION OF SEA-WATER *

	Parts per 1000 parts of water	Tons per cubic mile of sea-water
Sodium chloride	27.213	128,284,403
Magnesium chloride	3.807	17,946,522
Magnesium sulphate	1.658	7,816,053
Calcium sulphate	1.260	5,939,747
Potassium sulphate	0.863	4,068,255
Calcium carbonate	0.123	579,832
Magnesium bromide	0.076	358,270
	35.000	164,993,082

* Armstrong and Miall, 4 and 20.

Immense quantities of common salt are prepared from sea-water by solar evaporation along the seaboards of China, India, Japan, and along the tropical coasts. In India, the annual production of salt from sea-water is estimated at 1.36 million tons, out of a total production of over 2 million tons. Large quantities of bitterns hitherto regarded as waste products are being utilized for the production of some chemicals.

Sea-water has an average density of 3.5-4°Be′. In the earlier stages of concentration, calcium carbonate, gypsum and some magnesium carbonate separate out till the density reaches 24.5°Be'. The deposition of common salt begins at a density of 24.5-25°Be'., and continues till it reaches 29°Be'. The salt that separate thereafter is very impure and cannot be readily separated from the mother liquors. Consequently, the preparation of common salt is stopped at this stage and the bitterns (29-30° Be'.) are run out of the *kyars* or salt pans.

AVERAGE COMPOSITION OF SEA-WATER BITTERNS

	Bitterns of 29°Be'.*		†Bitterns of 30°Be'.
	(Per cent.)	(G. per litre)	(Per cent.)
Sodium chloride ..	11.21	140.14	7.48
Magnesium sulphate ..	5.89	73.65	6.70
Potassium chloride ..	2.89	36.09	4.92
Magnesium chloride ..	10.30	128.80	15.04
Magnesium bromide ..	0.17	2.07	..

* Pioneer Magnesia Works ; † Vakil, Salt, 1945, 16.

The bitterns obtained at Okha Salt Works, which produce annually 125,000 tons of common salt, are processed at Tata Chemical Works for the production of potassium and magnesium compounds (*J. sci. industr. Res.*, 1946, **5**, 213).

During the concentration of bitterns, the salt which separates out between 29-32°Be'., consisting of very impure sodium chloride, is discarded. Carnallite, $KCl.MgCl_2.6H_2O$, mixed with sodium chloride, crystallizes out between 32 and 36°Be'. This is treated with water when magnesium chloride goes into solution, leaving behind potassium and sodium chlorides, from which the former is separated by fractional crystallization and purified. At some works the potash salts that separate out only between 34-36 Be'. are collected. These on washing yield directly a fertilizer grade containing 80 per cent. of KCl.

The bitterns of 36°Be. contain three important magnesium compounds, the sulphate, the bromide and the chloride. Crude Epsom salt, $MgSO . 7H_2O$, separates out when the bitterns are cooled to 10° and it is purified by recrystallization ; and bromine (q. v.) is recovered by treating the warmed residual bitterns with chlorine. At this stage the tail liquor contains mainly magnesium chloride with a considerable amount of colloidal organic matter and at 37.5°Be'. it may contain, MgO,30.7; $MgSO_4$, 4.76 ; and KCl, 0.46 per cent.

This liquor is further concentrated in direct-fired open evaporators for obtaining magnesium chloride. During concentration, temperature rises considerably, charring organic matter, which is subsequently destroyed by the addition of an oxidizing agent. When the liquor attains a temperature of 160-162°, it is poured into drums made of galvanized iron sheets, each of which holds 5-6 cwt. of fused magnesium chloride. On cooling, it solidifies into a snow-white mass. Magnesium chloride is also marketed in the form of flakes prepared from the fused mass.

The magnesium sulphate content of some bitterns is too low to be economically recovered by artificial refrigeration, and too high to be tolerated as an impurity in the magnesium chloride produced. In such cases, the liquor at 162° is transferred to a settling tank, and allowed to cool down to 120-130° when all the magnesium sulphate separates as kieserite, $MgSO_4.H_2O$, and settles to the bottom. Magnesium chloride which is still liquid at this temperature is poured into drums.

Magnesia, MgO, is now prepared in large quantities directly from sea-water (*Industr. Engng. Chem.*, 1936, **28**, 383). The Tata Chemicals use a portion of the tail liquors from the bromine recovery plant for its manufacture. Any sulphate present is precipitated by the addition of requisite amount of calcium chloride solution, and separated out. The liquors are then reacted with quicklime in a rotary slaker, when magnesium hydroxide is precipitated and forms a slurry. This is thoroughly washed with large volumes of water, filtered, and calcined in a rotary furnace to yield magnesia or periclase. The plant has a rated capacity of 20 tons of magnesia per 24 hours.

The Khursheed Salt Works near Karachi also manufacture Epsom salt, potassium chloride and magnesium chloride from bitterns (Vakil, *loc. cit.*, 34).

KHARAGODA AND KUDA BITTERNS

The two large salt works in the Rann of Cutch are situated at Kharagoda and Kuda. The Rann is a vast flat saline tract, scarcely above sea level, and is completely flooded by sea-water during Aug. and Sept. At the end of Dec., water begins to disappear by percolation and evaporation. Edible salt is manufactured from natural brine obtained from wells dug into the Rann during Oct. to middle of May. Annual production is over 120,000 tons. The brine has a density of 14-18°Be'., and its composition is similar to that of sea-water of same density (Vakil, *loc. cit.*, 22 ; *vide* also Turner, *Dept. Industr., Bombay, Bull.* No. 2, 1920).

ANALYSIS OF KHARAGODA AND KUDA BRINES

(Per cent.)

	Kharagoda (Sp. gr., 20.5°Be'.)	Kuda (Sp. gr., 21.3°Be'.)
Calcium carbonate ..	0.012	0.016
Calcium sulphate ..	0.440	0.421
Sodium chloride ..	14.668	16.038
Magnesium sulphate	0.486	0.510
Potassium chloride	0.414	0.275
Calcium chloride ..	..	..
Magnesium chloride	4.636	4.647
Magnesium bromide	0.072	0.057
Total solids	20.728	21.964

Kharagoda bitterns have been exploited for the manufacture of magnesium chloride and Epsom salt since the first World War, by the Pioneer Magnesia Works, and the Kuda bitterns are being exploited by the Mayurdhwaj Magnesia Works. The present annual production of magnesium chloride of these two concerns is 3,000 and 1,000 tons respectively.

Since 1939, the Pioneer Magnesia Works have been recovering fertilizer grade potash salts, pure potassium chloride, 85 per cent. magnesia, etc. They have also erected a plant for bromine recovery (*J. sci. industr. Res.*, *loc. cit.*, 211).

SAMBHAR BITTERNS

The deeply coloured bitterns left after the preparation of edible salt from the saline lake waters of Sambhar have a density of 30-31°Be . and possess an offensive odour. They differ from sea-water bitterns in composition, and contain sodium sulphate and sodium carbonate, but no magnesium or potassium salts (Aiyar, *J. sci. industr. Res.*, 1944, **3**, 198).

The salt which separates out on further concentration is called ' bittern salt ' and shows considerable variations in composition (*vide infra*). It is dirty pink in colour and has a foul smell due to sodium sulphide. Exposure to sun and rain improves its colour and smell. This salt is not fit for edible purposes, but may be put to several agricultural and industrial uses, in which the presence of sodium sulphate and carbonate does not matter. During the last War, owing to shortage of edible salt, bittern salt was used for curing hides and skins, and was found to be as good as ordinary salt (Aiyar, *loc. cit.*).

It is estimated that the annual production of bitterns from Sambhar is 12.5 million c.ft., containing 1.2-4.5 lakhs of tons of mixed salts. The output of bittern salts in 1944 was 9,260 tons and this was sold to the hide and skin industry at the rate of As. 2-9 per md. f. o. r. Sambhar.

COMPOSITION OF SAMBHAR BITTERNS AND BITTERN SALTS

(Per cent.)

	Bitterns	Solids from bitterns	Bittern salt	
			From city bitterns area	From East Lake bitterns area
Sodium chloride	19.5	62.1	69.4—77.0	86.8
Sodium sulphate	6.8	21.8	11.3—18.0	6.5
Sodium carbonate	5.1	12.0	7.3—8.3	2.4
Sodium bicarbonate (including sodium sulphide and silicate)		4.1	1.2—2.5	0.1

BITUMEN

The International Committee on " the nomenclature of materials and processes used in the construction of roads " has defined bitumen as ' mixtures of natural pyrogenous hydrocarbons and of their non-metallic derivatives, which may be gaseous, liquid, viscous or solid, but must be completely soluble in carbon disulphide.' This covers a large range of petroleum products as well as the soluble material in tar. To distinguish tar products from asphaltic bitumen, the latter has been defined as " natural or naturally occurring bitumen prepared from natural hydrocarbons or from derivatives of natural hydrocarbons by distilling, oxidization or cracking ; solid or viscous, containing a low percentage of volatile products ; possessing characteristic agglomerating properties and substantially soluble in carbon disulphide." Asphalt is a mixture of bitumen with mineral matter, either prepared artificially or occurring naturally. In nature, asphalts are formed by the evaporation or distillation of crude petroleum, and some rocks, usually limestone, are impregnated with bitumen.

Natural asphalt occurs in large quantities in Trinidad and Bermudez. It is estimated that the ' pitch ' lake in Trinidad still contains 10-15 million tons of asphalt. Trinidad asphalt consists of bitumen, 38 ; water, 29; and mineral matter, 33 per cent. Bermudez asphalt contains about 64 per cent. pure bitumen and about 10-40 per cent. of water. Rock asphalts occur in Val de Travers, Zimmer, Ragusa and some parts of the U. S. A.

In India, stray occurrences of asphalt have been reported in the Deccan Trap dolerite of the Sewri Quarry, Bombay Island (*Rec. geol. Surv. India*, 1922, **54**, 117) ; in Poonch State, Kashmir (*Mem. geol. Surv. India*, 1928, **51**, 319) ; and in Bilaria, Jodhpur State. However, none of these is of any economic importance.

The oil field near Chakwal, Jhelum dist. (Punjab), has recently produced a crude oil with an unusually high percentage of bitumen. Bitumens prepared from the oil of Dhulian field are being regularly supplied by the Attock Oil Company Ltd.

There are four tests to determine the suitability of bitumen for road work. The bitumen content is determined by its solubility in carbon disulphide. The melting or softening point gives the temperature at which the bitumen begins to flow freely. The ductility of bitumen is the distance in cm., to which a standard briquette of bitumen at a temperature of 25° can be drawn out without breaking, when the ends are pulled apart at the rate of 5 cm. per minute. The penetration test is a measure of the degree of hardness or consistency of the bitumen.

Asphaltic bitumen, obtained as the undistilled residue of petroleum refining, is a black solid or semi-solid material. There are three types known in trade. Steam refined or straight-run asphaltic bitumens are made by the straight distillation of suitable crude oils or residues from crude oil, the more volatile products being distilled off, leaving behind the required grade of asphaltic bitumen. During distillation, steam is injected into the oil, so that distillation can be carried out at a lower temperature, thereby avoiding cracking or decomposition of the oil. Blown asphaltic bitumens are produced by blowing air through molten, steam-refined asphaltic bitumen. As the blowing is continued, it attains a rubber-like consistency ; its melting point rises and its ductility decreases. This variety has good weathering properties, and does not easily undergo changes in protective properties on exposure or with changes in climate. Pitch or ' Z ' type of bitumen is made by the distillation of residues from cracking plants.

For certain types of road work, it is found desirable to use bitumens, which are liquids at ordinary temperatures. Cut-backs and emulsions are two such varieties. Cut-backs are mixtures of asphaltic bitumen and a volatile solvent such as kerosene or creosote. ' Colas ' is a typical example of the emulsion type. It contains about 56 per cent. of asphaltic bitumen, water and a small quantity of soap.

Asphaltic bitumen is most useful in road-making, where it functions as a cement or binder for the mineral aggregate. It is resilient and flexible and can, therefore, withstand changes in temperature, and stresses of traffic. There are three ways of building a bituminous road surface, *viz.*, surface dressing, grouting and pre-mixing. Each of these methods has innumerable variations in detail, and the surface can also be made by a combination of all these methods.

The application of asphaltic bitumen in industrial processes are numerous. In the U. S. A., it is used in the manufacture of roofing felt. The impermeability of bitumen to water makes it an excellent material for the manufacture of waterproof fabrics, paper, etc. A coating of asphalt prevents structures from damage due to moisture. Owing to its high dielectric strength, asphaltic bitumen serves as a good electric insulator. Asphalt-coated fabrics are used as insulating tapes for electric cables, and asphaltic bitumen is used in junction boxes. Other industrial applications of asphaltic bitumen are in the manufacture of accumulator cases and other moulded articles, in the protection of buried pipe lines and steel pipes intended for carrying water, and in the production of bituminous paints and coal briquettes. In recent years, asphaltic bitumen has been finding important use in hydraulic engineering for waterproof and protective revetments.

During '40-45, the Burma Oil Co. (Digboi) produced 21,487 tons of bitumen, and the Attock Oil Co., 5,124 tons.

Bitumen is mainly used for road-making, and Government purchases during the War increased from 13,058 tons in '40-41 to 1,86,871 tons in '44 and 1,74,683 tons in '45. The price of bitumen which was firm at Rs. 195 per ton in '41-42 reached a peak of Rs. 260 per ton in '44, and declined to Rs. 214 per ton in July 45 (Govt. India, Petroleum Directorate).

IMPORTS OF ASPHALT AND BITUMEN

(Qty. in 1,000 tons, and val. in lakhs of Rs.)

	Qty.	Val.
Annual av. for the quinquennium ending—		
33-34	32.8	25.4
'38-39	39.9	23.9
'43-44	60.0	146.3
In '44-45	176.5	238.9
„ '45-46	214.4	293.8

Before the Second World War, imports were mainly from Egypt, 36 ; the U. S. A., 34.4 ; and Mexico, 24.3 per cent. In recent years Iran has been supplying considerable quantities of bitumen (67,728 tons in '43-44).

Imports are subjected to a preferential revenue duty. In 1947 the preferential rate in the case of asphalt from a British colony was 18 per cent. *ad valorem* as against a standard rate of 30 per cent. *ad valorem.*

For road surfacing, India imports mostly bitumen and there is no appreciable import of road tars into India. The quantity of road tar produced in the country rose from 22,000 tons in '33 to a peak of 46,000 tons in '42 (Fielder, *J. sci. industr. Res.*, 1944, **4**, 528).

BLEACHING POWDER

Bleaching powder or 'chlorinated lime' is a dull white powder with a pungent odour slightly different from that of chlorine. It is obtained by the chlorination of hydrated lime :

$$Ca(OH)_2 + Cl_2 = Ca(Cl)(OCl) + H_2O.$$

But the reaction is never complete and most commercial samples contain 32-35 per cent. of available chlorine, *i.e.*, the amount of chlorine evolved on the addition of acids :

$$Ca(Cl)(OCl) + H_2SO_4 = CaSO_4 + Cl_2 + H_2O.$$

Bleaching powder is unstable and rapidly deteriorates in a tropical climate. The decomposition is accelerated by certain catalysts, such as iron, manganese, etc. Even under the best conditions of storage it tends to lose almost all its available chlorine within a year.

Bleaching powder is chiefly employed for bleaching cotton yarn and textiles, and paper pulp. It is also used as a disinfectant, especially for sterilizing wounds, surgical dressings, etc., and in water purification and sanitation. Sometimes it forms a source of chlorine as in the preparation of chloroform.

However, owing to its instability, bleaching powder is being rapidly displaced by new bleaching agents. In 1923, the production of bleaching powder in the U. S. A. was 147,000 tons and only 16,700 tons in 1939 (Riegel, 107). 'Bleach liquor,' which is now extensively used, is prepared fresh by passing chlorine into milk of lime containing 1-1.5 lb. of slaked lime per gal. of water, maintaining the temperature at 30-40°. It contains more available chlorine, calculated on the quantity of lime employed, than bleaching powder. Further, chlorine itself, and freshly prepared sodium hypochlorite (available chlorine, 10-15 per cent.) are now widely used in textile mills, especially for bleaching fine quality goods, to avoid traces of calcium salts which interfere in the dyeing process. 'High Test Hypochlorite' containing 65-75 per cent. of calcium hypochlorite, and also the pure hypochlorite are coming into more general use (Riegel, *loc. cit.*). These are stable and more than twice as strong as bleaching powder.

The two principal raw materials required for the manufacture of bleaching powder are high grade lime and chlorine. The latter is now mostly obtained as a by-product during the electrolysis of brine for the manufacture of caustic soda. When used for the chlorination of lime, it should be free from hydrogen to avoid explosions in reaction chambers.

The quality of lime required is of the utmost importance. Generally, a very pure fat lime (CaO, 95 per cent.), which slakes readily to yield a large volume of slaked lime (over three times the vol. of CaO used), is employed. It should contain less than 2 per cent. of carbonate, 0.5 per cent. of iron oxide, 2.0 per cent. of magnesium oxide, and no cobalt or manganese. The lime after slaking should be stored for some time before use, and its moisture content may be 4 per cent. (Searle, Limestone and its Products, 1935, 601 ; *vide* also *Industr. Engng. Chem.*, 1947, **23**, 303).

When chlorine was being prepared in a dilute form by the Weldon or the Deacon process, chlorination of lime was carried out in closed chambers. Since the commencement of the manufacture of chlorine by the electrolytic process, numerous plants have been designed to make the process a continuous one. Of these Krebs-Beckman towers built of reinforced cement concrete are now the standard (*Chem. metall. Engng.*, 1926, **33**, 460). Each tower is 8-9′ in diameter and about 30′ high, with a production capacity of 2.5-3.5 tons of bleaching powder in 24 hrs. of continuous operation, and is built about 10′ above the ground to accommodate the discharge mechanism and the driving gear of the agitator shaft.

The tower is divided into eight chambers by cement concrete slabs. A rotating vertical shaft, provided with plough blades, one set for each chamber, passes through a central hole in the slabs. There is provision for the circulation of refrigerated brine through cooling coils embedded in the concrete slabs, to keep the temperature of reaction chambers below 40°. Each chamber has a window fitted with a glass door, to serve as a man-hole, and as a safety blow-off, in the event of an explosion. The agitator mechanism and the interior of the chambers are painted with a bituminous composition containing asphalt, china clay, asbestos, etc.

Slaked lime is fed by gravity and travels slowly and successively through all the chambers. It comes into contact with air-diluted chlorine, which enters just a little above the bottom chamber and travels counter-current to lime. The flow of hydrated lime, air and chlorine is regulated, and the lime on the concrete slabs is continually raked up by the plough blades. The exhaust gases contain only traces of chlorine.

In the chlorination of lime in Krebs-Beckman towers, the humidity of air and chlorine is carefully controlled, and the temperature in the chambers is maintained at or below 40°. The moisture content of lime may vary from 4-7 per cent., and the best results are obtained when it is at the former figure. The concentration of chlorine may be 60 per cent.

Bleaching powder leaving the tower is stored in cast-iron drums or wooden barrels. Its packing density is 70-93 lb. per c. ft. To increase its keeping qualities, it is sometimes mixed with quicklime to yield ‘ tropical bleach ’ containing 25 per cent. of available chlorine (Rogers, 1, 452).

The average annual imports of bleaching powder into India during the quinquennium ending ’38-39 were 10,060 tons, valued at Rs. 11.6 lakhs, and the U. K. was the most prominent supplier (over 70 per cent.). Indian consumption of bleaching powder in 1944 was estimated at 11,100 tons, distributed thus : paper mills, 5,400 tons ; textiles and surgical dressings, 3,600 tons ; public health requirements, 1,800 tons; and manufacture of chemicals like chloroform, 300 tons (Thomas, Rep. Develop. Industr.

War Supplies, 1944, 29). The Tariff Board estimates the present demand at 13,600 tons, and this is likely to remain steady for a few years to come (Rep. Caustic Soda and Bleaching Powder Industry, 1946, 12).

The manufacture of bleaching powder in India commenced during the War, and the total production capacity of the three plants in operation is 8,250 tons per annum [Mettur Chemicals (Mettur), 2,500 tons; Tata Chemicals (Okha-mandal), 4,500 tons; and Rhotas (Dalmianagar), 1,250 tons]. The Govt. factory at Rishra (Bengal) erected at the instance of the Defence Dep. to produce 3,000 tons of bleaching powder per annum was unfortunately never operated successfully. The estimated production during each of the years 1945 and 1946 was only 4,600 tons, the only regular producer being the Mettur Chemicals. Indigenous production is expected to rise to 6,000 tons in '48-49. The total manufacture of Rhotas is intended for consumption in their own works.

The consumption of raw materials per cwt. of bleaching powder manufactured at Mettur is rather high (limestone, 1.46 cwt., and chlorine, 0.32 cwt.), and available chlorine in the finished product is low (28-30 per cent.).

Annually, some 7-8 thousand tons of bleaching powder will continue to be imported, and in the interest of the consuming industries, imports are duty free. While the landed cost and the selling price per cwt. of bleaching powder before the War (1939) were Rs. 4-8 and Rs. 6 respectively, the corresponding figures now are Rs. 11-5 and Rs. 13. The Tariff Board has estimated the cost of production per cwt. of Mettur bleaching powder now (Oct. '46-Dec. '47) at Rs. 11-3 and its fair selling price at Rs. 13-2. After 1st Jan. '48 these figures are expected to come down to Rs. 9-6 and Rs. 11-5 respectively. The recommendation of the Board to grant a subsidy of Rs. 1-13 per cwt. on the sales of Mettur bleaching powder up to 31st Dec. '47, assuming the landed cost of the imported material remaining steady at Rs. 11-5 per cwt., has been accepted by the Government.

BOBBINS

Bobbins are chiefly made of wood and are used to convey yarn from one machine to another in textile mills. The cotton textile industry requires various types of bobbins differing in size, taper and shape, such as slubbing and roving tubes, ring rabbeths, ring weft pirns, universal pirns, Wadia pirns, etc. The bobbins used in woollen mills are similar to those used in cotton mills, but differ in size. Only two types of bobbins are used in jute mills, rove bobbins for roving, and spinning bobbins for yarn spinning.

A good bobbin wood should be straight-grained, sufficiently hard, and of medium weight (40-45 lb. per c.ft.), and must not crack or split during boring or turning, and should season without much shrinking. The wood is also required to withstand the strains developed in high-speed machines. Further, it should be available in commercial quantities, and should be properly seasoned. Imported bobbins are usually of beech (*Fagus* spp.) and birch (*Betula* spp.), and also of maple (*Acer.* spp.) and alder (*Alnus* spp.) Beech is used in England especially for bobbins of larger size, such as slubbing and roving tubes. Both white and yellow birch are imported ; bobbins made from the former are of better quality. Imported timbers, such as Canadian birch and maple, are used for lighter cotton-mill bobbins, such as ring rabbeths and weft pirns.

Birch and maple occur in Kashmir, and to a small extent in some of the extreme northern forests of the Punjab, but at present they are inaccessible. *Haldu* (*Adina cordifolia*) is the chief wood used in India for the manufacture of bobbins. Others are *kaim* (*Mitragyna parvifolia*), *kanju* (*Holoptelea integrifolia*), and *kuthan* (*Hymenodictyon ex-*

celsum). A number of other species are also recommended for trial (*vide* Rehman, *Indian For. Bull., New Series*, No. 122, 1943; and Trotter, 1944, 198). Bobbins made from Indian woods have only 30 per cent. of the life of imported bobbins.

Haldu and *kaim* are very brittle, and if stored as logs or as thick squares, they are liable to severe end splitting or surface cracking. Before use, the wood should be thoroughly seasoned, otherwise, the finished bobbin will not retain shape and may twist or split. Immediately on receipt, the logs should be converted into boards and scantlings of required thickness, and stacked for air-seasoning, or kiln-dried. For air-drying, boards up to 1½″ thickness and 2″ square scantlings should be kept stacked for at least 3 months. If a timber seasoning kiln is available, the wood is dried in it for about a fortnight. Rehman (*loc. cit.*) also recommends combined air and kiln-seasoning. The boards and scantlings are air-dried for about a month when the moisture content goes down to about 25-30 per cent. They are then cut into bobbin blanks and kept in a hot air kiln for about a fortnight, when moisture content drops down to about 10 per cent.

Other materials required for making bobbins are glue, sand-paper, linseed and machine oils, black enamels, paints and varnishes, tin and terne plates and copper and brass sheets.

Ordinarily, only a few simple machines, such as sawing machines, boring and drilling machines, turning lathes, etc., are required for making bobbins, and most Indian factories are equipped with locally made machinery. For accuracy of production, automatic bobbin making machinery is necessary, and at present only the Bareilly factory is equipped with such a plant.

Boring the blanks is the first stage in the manufacture of bobbins. This is carried out slowly and in several stages in order to avoid breakage of timber. The blanks are then roughed and passed on to turning machines where they are brought to the final shape and size. Subsequently grooves are cut at the ends and the metal shields fixed in a hooping machine. They are passed on to boring spindles where the bore is increased in 2 or 3 stages so that the bobbins fit in correctly on the spindles in the mills. Ring rabbeths and pirns are given a tapering bore, and slubbing and roving tubes, a uniform bore. The bobbins are finally sand-papered, painted and varnished.

Ring rabbeths and pirns are very often black-enamelled to make them moisture-proof. Each bobbin is tested for correct fitting on the appropriate spindle, and also for true running by rotating the spindle at mill revolutions so that there is no vibration or wobble. Slight differences in fitting are corrected by rincing. Very often tips of pirns and ring rabbeths are coloured to distinguish various types of yarns.

Jute mill bobbins are made in several sizes, but the sizes most in demand are 10″×5″ for rove bobbins, and 4″×2⅝″ 5″×3¼″, and 6″×3½″ for spinning bobbins. Rove bobbin is made up of separate shank and end pieces, as it is too large to be made in one piece, and the worn out ends are easily replaced by new ones A central hole is bored through seasoned blanks, and these are turned to proper shape, and the shanks and end pieces are attached to each other by means of hide glue and steel pins. The hole in the spool is then reamered to proper size, and the built-up bobbin turned to final shape. It is then sand-papered and finally immersed in oil. Spinning bobbins, which run at higher speeds, are generally made from single pieces and with a higher degree of precision.

Before the War ('39-45), some aluminium bobbins were also manufactured in Calcutta, but this was stopped during the War, owing to demand for more essential uses of the metal.

The manufacture of cotton textile bobbins was started during the '14-18 War with the establishment of a Govt. sawmill and turnery at Bareilly. Before World War II, the Indian Bobbin Co., Bareilly, was supplying a small proportion of Indian requirements. But their products could not successfully compete with the Japanese bobbins, which were much cheaper. In the Bombay province, a number of smaller concerns were also producing bobbins both from imported and indigenous woods. The industry received encouragement during World War II, and a large number of concerns came into existence. But the Bobbin Control Order of '43 led to the closing down of many small concerns and now there are about 105 factories, mostly located in Bombay and Ahmedabad. The biggest of these is the Bharat Bobbin Works at Ahmedabad.

The indigenous manufacture of bobbins for jute mills was also started during the first World War. With the flow of imports after the War, the industry suffered a setback and collapsed. During World War II, it was again started mainly in Calcutta, and was able to supply all the bobbin requirements of jute mills. The annual production capacity amounted to 1,86,000 gross bobbins, and 42,000 gross bobbin-ends. There are at present about 20 firms in and around Calcutta, the largest of which is the Hindustan Bobbin Factory, producing about 550 gross bobbins and 1,500 gross bobbin-ends every month with a labour force of about 125. Bobbins for woollen and silk industry are generally imported. Some are also made in Bombay, Bareilly, and Bangalore.

Since the beginning of the War ('39-45), Indian factories have been supplying all the requirements of the jute mills, and a major portion of the requirements of the cotton mills. The industry has been fairly successful in producing good quality slubbing and roving tubes and skewers. In the case of ring rabbeths, weft pirns, Wadia pirns and ring doublers, the finish is good, but the fittings are generally imperfect. Durability is below standard due to lack of suitable timbers, and imperfect seasoning. *Haldu* and *kaim*, although considered fairly satisfactory for the manufacture of heavier types of bobbins, are not well suited for lighter varieties, and a suitable substitute for imported beech and birch is yet to be discovered.

AVERAGE ANNUAL IMPORTS OF BOBBINS INTO INDIA

(Lakhs of Rs.)

Quinquennium ending—	
'38-39	32.6
'43-44	54.6
In '44-45	81.1
,, '45-46	94.7

In the quinqennium ending '38-39 imports were mainly from the U. K. (58 per cent.), Japan (28 per cent.), and Germany (10 per cent.), and in subsequent years, from the U. K. (over 75 per cent.). The import duty on bobbins is 10 per cent. *ad valorem* and since Mar. '46, the duty on wood for the manufacture of bobbins has been abolished.

The pre-War annual consumption of all types of bobbins used in cotton textile mills was about 340,000 gross and in '45 it rose to nearly 477,000 gross. During the last 4 years ('43-46), Indian manufacturers have produced 746,000 gross bobbins.

COTTON MILL BOBBINS

Type	Pre-War av. annual imports* (1,000 gross)	Pre-War annual requirements* (1,000 gross)	Production in '46* (1,000 gross)	Cost of production in '45 (Rs./gross)†
ubbing tubes	10.0	34·3	16.0	100
oving tubes	24.0	51·9	15·7	80
cewers, slubbing	1.3	8.6	3·1	..
kewers, roving	3·0	10.3		
ing rabbeths	67.0	107·9	49·5	37
ing weft pirns	200.0	116.7	98·7	36
thers	..	4·7 (Wadia pirns)	17·3	36
Total	305·3	334·4	200.3	

* Textile Commissioner ; † All-India Bobbin Manufacturers Assoc., Bombay.

If the imports into Bengal are taken to represent only jute mill bobbins, the value of average annual imports of such bobbins during the quinquennium ending '38-39 was Rs. 5.9 lakhs, in the following quinquennium, Rs. 12.7 lakhs, and during '45-46, Rs. 9.6 lakhs.

BOILERS

Boilers are of two kinds : (1) fire-tube or smoke-tube boilers, in which the combustion gases pass through tubes submerged in water in the boiler, and (2) water-tube boilers in which water passes through tubes surrounded by fire. Modern high pressure and high capacity boilers are of the latter type.

JUTE MILL BOBBINS

Type	Estimated requirements* (1,000 gross)	Present production (1,000 gross)	Cost of production Rs./gross
Roving bobbins	10.0	13.5	178/-(10"×5")
Spinning bobbins	40.0	26.4	73/4-(6"×3¼") 46/12-(4"×2⅝")
Bobbin-ends	25.0	30.0	48/-

* All-Bengal Bobbin Manufacturers Association.

Fire or smoke-tube boilers include Vertical, Lancashire, Cornish, Locomotive, Scotch marine and Economic types. All these are internally fired, except the last, and are seldom employed for pressure exceeding 175 lb. per sq. in. or for evaporative capacities over 12,000 lb. of water per hr. Lancashire boilers are popular in India and have an efficiency of 70 per cent. Their average life is about 30 years and some of them have lasted nearly 50 years. Economic boilers have a higher overall efficiency (75 per cent.) and are easier to work and to clean.

Type of boiler	Evaporative capacity (lb. of water/hr.)
Vertical	180—6,000
Cornish	1,000—4,000
Locomotive	2,000—9,000
Lancashire	1,700—12,000
Economic	1,500—20,000

Water-tube boilers are quick-steaming and their capacity ranges from a few hundred pounds to over 800,000 lb. Their overall efficiency is 86-90 per cent., and their average life, 20-25 years. The leading English types are made by Messrs. Babcock and Wilcox Ltd., Marshall Sons and Co., Ltd., the Stirling Boiler Co., Ltd., Clarke, Chapman & Co., Ltd., and the John Thompson Watertube Boilers Ltd., of Great Britain.

In India, vertical boilers are employed in most of the collieries, mica mines and distilleries, and Lancashire, Cornish and Loco boilers, in textile mills, collieries and some rice mills. Water-tube boilers are mainly used in power houses and bigger industrial plants such as sugar, cement and paper factories and to a limited extent in textile mills and collieries. The iron and steel industries use all types.

Boilers are invariably fitted with certain controls: water-level gauges, steam pressure gauges, safety valves, feed check valves, fusible plugs and blow-off valves. For efficient working, they are provided with economisers, superheaters, feed-water pumps, pre-heaters, water regulators and reducing valves.

Certain precautions have to be observed in the working of a boiler. It should be carefully lagged with non-conducting asbestos composition for preventing losses by radiation. The furnace should be frequently cleaned, and the sludge or soft scale regularly removed. Scale and soot should be removed from the inside of the shell and tubes.

The presence of impurities in feed-water leads to various troubles. Dissolved oxygen and carbon dioxide may cause corrosion and this may be avoided by increasing the alkalinity of water by the addition of sodium sulphate and caustic soda. Suspensions usually consisting of insoluble clay-like material combined with organic matter, consolidate into a hard deposit and cause priming (discharge of water with steam) and foaming. Calcium salts produce scale formation, and magnesium and sodium salts cause corrosion. High concentration of caustic soda leads to caustic embrittlement of boiler metal. The soluble salts are maintained at a minimum by softening feed-water. In industrial plants, feed-water is usually softened by the lime-soda or base exchange process. Sometimes softened water or water from the main supply is re-treated with 'boiler compounds' to minimise corrosion, etc.

Under the Indian Boilers Act, 1923, boilers must be registered and unless the standard conditions in respect of materials, design and construction are satisfied no certificate is issued for the use of boilers. The certificate gives the maximum pressure at which the boiler should be worked, the load to be placed, safety valves or thickness of washers or ferrules required as safeguard against overloading, and the date and pressure of the last hydraulic test, and when applicable, of the main steam pipes.

With the exception of some railway locomotive boilers made in the Railway Workshops (Humphries and Srinivasan, Constr. Locomotives India State Ry. Workshops, 1940) all boilers for industrial and other purposes are imported. The Tata Locomotive and Engineering Co. (Telco Works), Tatanagar, is now fully equipped with modern machinery for the manufacture of boilers according to the standards of the Indian Ry. Bd. The Company is manufacturing boilers for locomotives and road rollers. The works are also turning out miscellaneous accessories for boilers, such as, ashpans, smoke boxes, tank reservoirs, etc. Most of the raw materials are being supplied by the Tata Iron and Steel Co. Cold drawn steel tube and flues, high and low pressure steel and copper piping, and a few proprietory articles are imported.

AVERAGE ANNUAL IMPORTS OF BOILERS INTO INDIA

	Rs. (lakhs)
During the quinquennium ending—	
'38-39	93
'43-44	55
In '44-45	79
,, '45-46	112

During the quinquennium ending '38-39, 83.3 per cent. of the imports were from the U. K. The av. annual exports of boilers in tons from the U. K. to India during '35-39 were : internally fired boilers, 587 ; Loco type (for stationary purposes), 235 ; water-tube boilers, 3,863 ; other sorts, 547 ; Economisers, feed-water heaters and super-heaters, 932 ; and other boiler plants, 951.

Imports are subject to a revenue duty of 10 per cent. *ad valorem*.

BOOTS AND SHOES

Although the use of foot-wear in India dates back to remote times, its manufacture as an industry began in Agra, Delhi and the neighbouring places, only during the Mohammedan rule. The production of western types of shoes was introduced during the latter part of the Moghul period, in the neighbourhood of cantonments, to cater to Europeans employed in the army. Gradually Indians also began to take to Western types of foot-wear, and soon the industry expanded and spread to other big cities.

Large scale factory production began with the manufacture of leather, by the Government Harness and Saddlery Factory at Cawnpore, in 1857. A little later two more factories, the Foy Bros. (1872), and Cooper, Allen & Co. (1881) were established at Cawnpore for the production of army foot-wear. The first organised factories for cvilian foot-wear were started in 1900 with the establishment of the Stuart Tannery at Agra, and North West Tannery at Cawnpore. Other factories soon sprang up in some cities in the U. P. and also in Gwalior, Rewa, Bombay and Madras.

The Stuart Tannery, although it closed down shortly afterwards, was mainly responsible for the present large scale production at Agra, where its employees, trained in the system of division of work, opened a number of small factories. World War I gave an impetus, and numerous small concerns sprang up in almost every street in Agra. During this period, factories were also started in Calcutta, Bombay, and in various places in the Punjab. Before World War II, southern India had only small concerns.

Leather foot-wear in India is made mostly by *mochis* or cobblers. Indigenous types consist of *chappals*, sandals and *jooties*, resembling slippers. Western types of foot-wear are mainly used in urban areas. Hand-made shoes, which form the bulk of output, are manufactured on a large scale at Agra and Calcutta. Machine-made foot-wear is manufactured chiefly by Cooper, Allen & Co., Cawnpore, and Bata Shoe Co., Batanagar and Lahore.

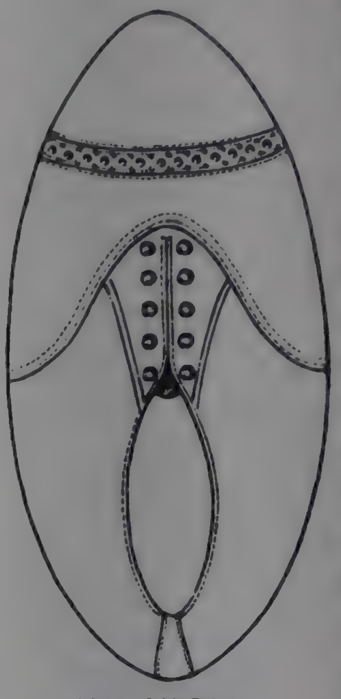
In Agra foot-wear manufacture is almost entirely a cottage industry. About 50,000 workmen are engaged in the production of 17 million pairs every year. During World War II, production, including that of army foot-wear, was almost doubled, and the number of small factories swelled up rapidly to at least 1,000, with nearly a hundred producing 35-100 pairs per day.

In Calcutta, more than 1,000 skilled Chinese workers are engaged in the manufacture of hand-made shoes, with about 6,000 Bihari *mochis* for sole-stitching. There are besides another 10,000 Bihari *mochis* in Calcutta, of whom some 3,000 are producers of modern shoes, and 7,000, of indigenous shoes. During pre-war years, Calcutta was producing about 3½ lakh pairs of foot-wear (*Dep. Industr., Bengal, Bull.* No. 86, 1941, 34). Chinese shoe-makers are also found in all big cities, and are responsible for a large output. Other important centres of production are Delhi, Lahore, Rawalpindi, Gwalior, Baroda, Bombay, Madras, and Bangalore.

MANUFACTURE OF BOOTS & SHOES

All types of leather boots and shoes are manufactured in India. A modern boot or shoe consists of an 'upper' which is attached to a 'bottom.' Each of the two parts may consist of a single piece of leather, or of two or more pieces. The upper and the bottom are attached to each other by means of thread, tacks, rivets, staples, screws, nails, adhesives, etc.

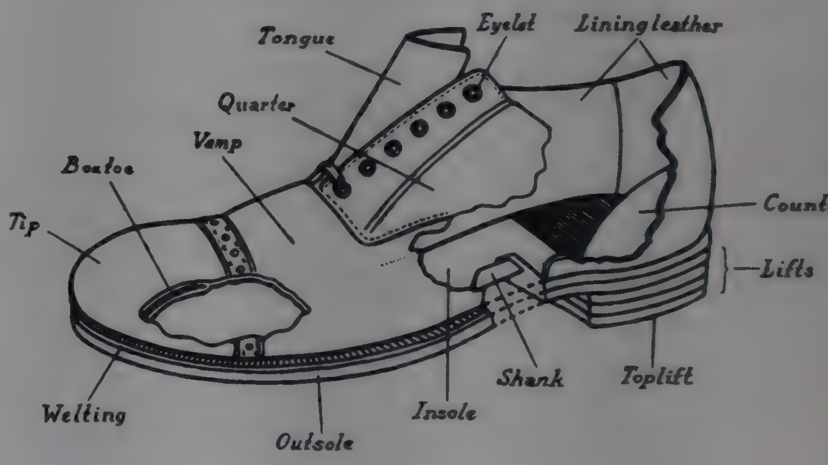
The upper of an ordinary shoe consists of an outside and a lining. The outside is composed of a vamp and a quarter, which may again be subdivided into other parts. The vamp is the complete lower part of the upper, and the quarter is the top portion of the upper above the vamp line. The interior of the upper is generally lined with soft leather or canvas.



AN 'UPPER'

The bottom of an ordinary shoe consists of a sole and a heel. The sole is generally composed of several layers, such as the outsole, the insole, and in some cases, the midsole. The heel is also made of several layers, or 'lifts,' of sole leather; or it may consist of a block of wood with a top leather lift. The insole is pasted inside with a sock and a heel pad.

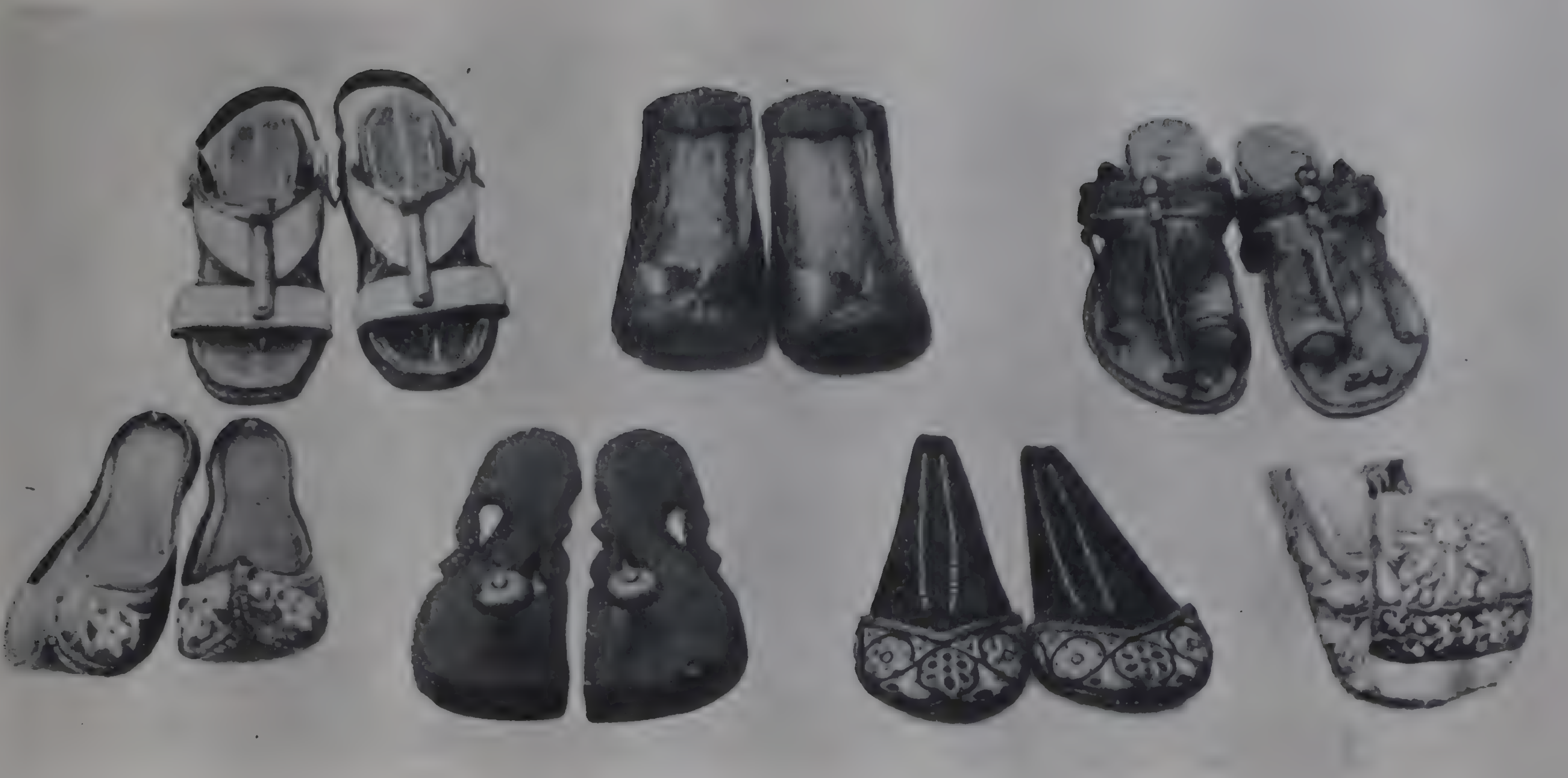
Other major components of a shoe are the stiffener or counter, toe puff, bottom filler, welt, etc. The stiffener is inserted between the outside and lining of a shoe upper at the back part, for strengthening, and for preventing it from sagging. The toe puff is a stiffener used under the toe cap to protect the foot. Bottom filler is used for filling the cavity between the insole and sole, and for giving a solid bed to which the sole is attached.



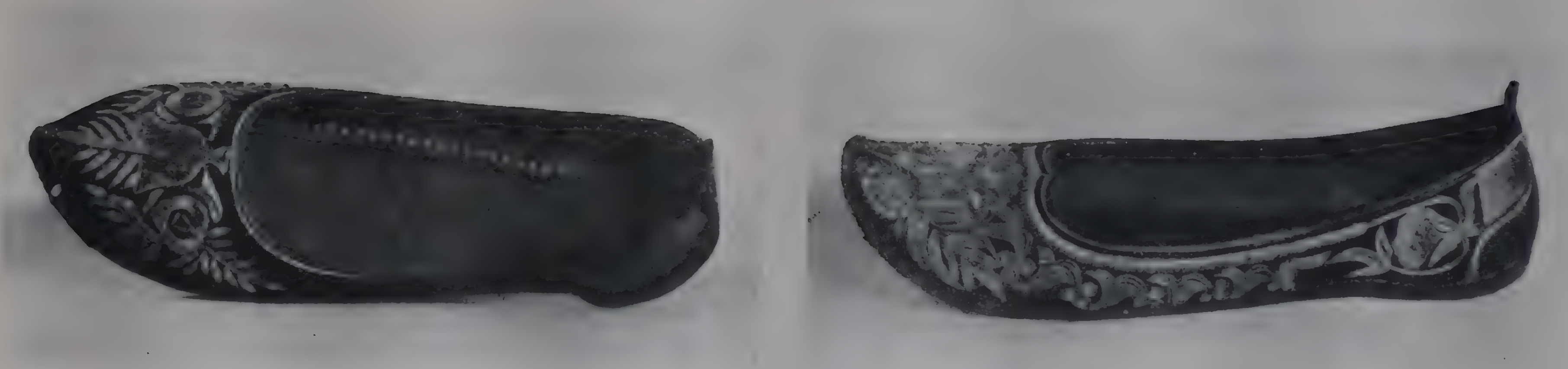
Component parts of a shoe.

The shank or waist piece is a short piece of tough material attached between the sole and insole, forming a bridge for the arch of

Pl. VI



1. INDIGENOUS FOOTWEAR



2. DELHI ZARI JOOTIS

3. DELHI ZARI JOOTIS

4. DELHI ZARI JOOTIS

the foot. It gives support and rigidity to the middle portion of the shoe.

The leather used may vary from light glace' kids to heavy leathers. The types used are : (*a*) cow and calf leathers, chrome-tanned, (*b*) cow and buffalo leathers, vegetable-tanned and curried, (*c*) cow and buffalo leathers, semi-chrome-tanned, (*d*) russet kips, vegetable-tanned and curried. Glace' kids, box and willow sides, box and willow calf, suede skins, imitation *sambur* leathers, patent leathers, glazed sheep skins, and reptile skins are employed for the uppers of quality shoes. Light skins, sheep and goat skins, calf leather, russet calf and cloth are used for lining.

Bottom stocks, such as, soles, heel lifts, welts, etc., are made from heavy leathers. Vegetable or chrome-tanned buffalo leather is generally used, but pit-tanned leather is superior. Impregnated toe puffs made from fabric are very common.

Chrome-tanned box and willow sides, kips and calf are manufactured principally at Calcutta, Cawnpore, and Madras, and in smaller quantities at Bangalore, Trichinopoly, Bombay and Sholapur. Higher and expensive grades of chrome upper leather are generally made at Madras and Cawnpore. Glace' kid and chrome patent leather come almost entirely from Madras, and nubuck leather (white buck leather for uppers), from Calcutta and Madras. Vegetable bag-tanned sole leather comes from Jullundur and other cities in the Punjab, and from the U. P., Calcutta and Bombay. Superior pit-tanned sole leather is manufactured in Cawnpore, Calcutta and Madras.

During the War, the manufacture of civilian foot-wear was stopped in most of the organised factories due to their pre-occupation with War orders, and the civilian trade slipped into the hands of cottage industries, and large quantities of hides were diverted to this channel. As a result, there was serious shortage of hides for the production of foot-wear and other leather equipment required by the Defence Services. Consequently, the Government had to impose several control measures on large producers of leather.

Soles and heels are often made of crepe rubber. Rubber sheeting from inferior grades may also be used. Sole and heel may be moulded from reclaimed rubber, either separately or in one piece (monolith soles). Moulded products are generally used in cheaper foot-wear, and soles are channelled for stitching.

Wooden soles, common in some parts of India and Burma, are made of *Croton oblongifolius*, *Gmelina arborea* and *Mitragyna rotundifolia* (Trotter, 1940, 174).

For wooden heels, mango (*Mangifera indica*) and *haldu* (*Adina cordifolia*) are used. The former is very satisfactory, and the latter is liable to crack during nailing. Other timbers recommended are *kaim* (*Mitragyna parvifolia*), *kanju* (*Holoptelea integrifolia*), *Gardenia* spp., *nimi chambeli* (*Millingtonia hortensis*), *Kydia calcyina* (Trotter, 1944, 199). In other countries maple wood (*Acer* spp.) is preferred for wooden heels.

Generally, steel, wood, bamboo, and sometimes leather are employed for shanks. Steel is generally used in ladies' shoes, and wood is preferred for men's and children's foot-wear. Bottom fillers, made of bonded granulated cork or leather scrap, should be waterproof.

Another indispensable requirement of foot-wear industry is grindery which includes such items as, thread, wire and tacks, rivets, eyelets, buckles, heel and toe tips. For these, India is entirely dependent on imports from the U. K. and the U.S.A. During the last War, owing to shortage of grindery, the method of foot-wear manufacture had to be modified to suit available materials. Small quantities of brass screwing wires, iron toe plates, and heel tips were made during the War, but not eyelets or iron nails. Production of heel and toe tips during '41 and '43 was 59.2 million pairs (Thomas, Rep. Develop. Industr. War Supplies, 1944, 18). Stains and polishes are now prepared in India.

Wooden lasts are generally imported. Some quantities are made by Batas with last making machinery, and at Agra by crude methods. Lasts are also made at Sialkot and Jullundur from *sissoo* and mango wood. Lasts generally have metal bottoms against which lasting tacks are clinched. Considerable quantities of cast-iron lasts are made at Agra.

The wood required for boot-lasts in addition to being tough, should also be able to stand repeated nailing. It should be fine textured, moderately hard, and of a medium weight, and must be able to maintain its shape indefinitely. *Dalbergia sissoo* (*sissoo*) is probably the best, and is popular in northern India. *Acer* spp. and *Prunus padus* (bird cherry) are considered second best. *Ehretia laevis*, *Gmelina arborea*, *Gardenia* spp., *Lagerstroemia flos-reginae*, *Mitragyna parvifolia*, *Polyalthia cerasoides* and *Zizyphus jujuba* are also considered useful (Trotter, 1944, 119). Lasts are made from beech (*Fagus* spp.) and hornbeam woods (*Carpinus* spp.) in foreign countries. With proper care a pair of lasts will serve for 7-8 years.

The production of foot-wear by machinery is a highly skilled industry in which careful planning and proper designing are of the utmost importance. The former has to take into account the availability of raw materials (leather and grindery), and the factory's equipment and capacity. In the latter the designer is required to produce attractive styles to suit the prevailing demand and to cut master patterns to those designs. The factories generally concentrate on one, or perhaps two types of foot-wear, and it is seldom that men's, ladies', children's and sports foot-wear are manufactured by the same firm.

The production of foot-wear by machinery involves several different operations, which may be grouped into seven major stages, *viz.*, clicking, bottom-cutting, preparing, lasting, and making and finishing.

Clicking, the cutting of upper components, is done mostly by hand, using tinplate patterns and hand clicking knives. The quality of upper and economy in cutting depend upon proper selection of materials, and upon the technical skill of the clicker. The components are carefully matched, and before closing they are skived (edges thinned down for ease in seaming), and beaded. Ornamental work, if desired, is done at this stage. The lining components stitched into a complete lining, are then attached to the upper by chain stitching. Four or five pairs of eyelets are inserted and clinched, and the upper is tightly laced before it goes for lasting.

Bottom-cutting involves the cutting of insole, outsole, midsole, heel lifts, welt, etc. The leather is pressed between rollers and the components are stamped out by press machines, containing hollow dies with cutting edges. Insoles are cut out of light leather, and those cut from heavier stock are skived to proper thickness. Welts are generally cut in the form of narrow strips from scrap sole leather. The sole pieces are then compressed, shaped, skived, moulded and channelled, to make them ready for attaching to the upper. Wooden heels for ladies' shoes are turned from rough blocks of wood and are then fixed with a top lift of leather or rubber.

The next operation is ' lasting.' The closed upper is pulled over lasts and fixed to the insole. The stiffener and toe puff are first cemented between the lining, and the upper and the insole are lightly fixed to the last with tacks. The edges of the upper are pulled over the last uniformly, and lightly secured to it, before being passed on to the lasting machine for more secure attachment. Here the sides, toe, and heel seats are in turn lasted by drawing the upper and lining tightly down to the last and permanently fixing it to the insole by tacks, staples, stitching, etc. After lasting, surplus upper material is trimmed, and the bottom is levelled and moulded to proper shape for attaching the sole.

The lasted upper is then bottomed in the making section. This involves the fixing of the outsole after insertion of fillers and shanks, and various methods of attachment are in vogue. In machine-sewing, the bottom is fixed to the upper by a vertical chain-stitch seam, in a Blake sewing machine. In staple welted attachment, the welt is stapled to the upper and insole, and the sole is fixed to the welt by stitching or riveting. This method has more flexibility than other metallic fastening methods. In Goodyear welted shoes, the sole is attached to the welt in a channel by a vertical lock-stitch seam. In making heavy shoes, such as army ankle boots, the midsole is solidly riveted and clenched on the lasted insole. The sole is then lock-stitched and the bottom is reinforced by screws.

Stitchdown is a direct attachment made with thread only, and is widely used for children's foot-wear, and gives a flexible foot-wear. Cementing gives a flexible attachment for light foot-wear, and is very popular. The sole is fixed to the lasted upper and insole, or to a stitched welt, by an adhesive. In pump shoes, the upper is lasted with cement or tacks, direct to the sole.

When the sole is nearly complete, the heels are permanently fixed with steel pins. Iron toe plates and heel tips are fitted to Army boots.

When a crepe sole is used, it is cemented to crepe midsole which is blake-sewn to the insole and upper, and the heel is attached by cementing. Soles made of rubber sheet or moulded rubber, and also monolith soles are machine-stitched, and heels are nailed. When wooden soles are used, the shoe is made in the ordinary way up to the attachment of the bottom, and the wooden sole is then screwed on, riveted, or cemented.

The bottom is then finished, and dressed with blacking or stains, and finally wax-polished. The lasts are next pulled out, sock linings and heel pads attached, and the upper and lining cleaned with soap. The shoes, placed over trees (last-shaped forms), are ironed to remove wrinkles, and finally dressed and polished. The finished shoes are wrapped in paper and packed in cartons.

Except the factories of Messrs. Cooper, Allen & Co. and Bata Shoe Co., which are completely mechanised, leather foot-wear in India is mostly hand-made. The majority of Indian shoe-makers generally employ an upper sewing machine, while carrying out all the other operations by hand. Some factories use machines for lasting, blake-sewing and bottom finishing. In large factories, other operations such as bottom cutting, perforating, eyeletting, skiving, etc., are also done by machinery.

RUBBER SHOES

The bulk of the so-called rubber shoes manufactured in India consists of rubber-soled canvas shoes (plimsolls). The upper is prepared by coating canvas with a thin layer of rubber. The lining material (unbleached cotton twill) is coated on one side with a thin layer of the rubber composition, and is covered firmly with the canvas upper. The material thus prepared is cut into uppers of different sizes by cutting dies.

The sole is different in thickness at the heel, shank and toe portions, and is cut from milled crepe rubber sheets. Foxing and toe guards are made of special rubber composition by extrusion. During the last War, jute soles replaced rubber soles in some canvas shoes.

In the making of the shoe, the upper components are pasted and lock-stitched into a complete upper. The completed upper is fitted with eyelets, laced, and lasted. Finally the sole is attached by means of rubber adhesive.

The cemented shoes are treated with steam for about 12 hours at about 300°F. and 3 atm. pressure. This makes rubber more flexible and durable. The shoes are then cooled for about half an hour, after which they are taken off the lasts, carefully checked, and packed into cartons.

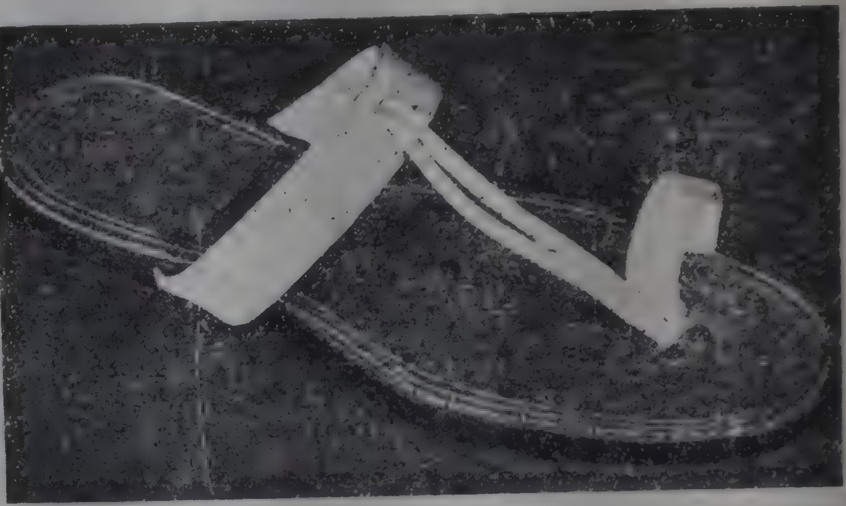
In manufacturing all-rubber waterproof shoes, the upper is cut from a calendered sheet of rubber composition.

Before World War I, rubber foot-wear, rubber-soled canvas shoes, and all-rubber shoes were being imported from the U. S. A. Cheaper Japanese products subsequently captured the market, and in 1931 imports from Japan reached 11 million pairs. The Bata Shoe Co. began the manufacture of plimsolls in India in 1933 and their capacity is now about 15 million pairs per annum. Before the last War, a number of Indian plimsoll factories came into existence, but several of these were assembling plants making complete shoes from imported Japanese components. Imports of plimsolls from Japan soon declined and in 1940 Indian producers exported 4½ million pairs.

INDIGENOUS FOOT-WEAR

Indigenous types of foot-wear include *mundas*, *nagras*, *Peshawari chappals*, *jooties*, *chappals*, sandals, half slippers, etc. These are manufactured all over the country, every province having its characteristic types. Coarser *mundas* are mainly used by the poorer classes, whereas *chappals*, etc. are worn by the upper classes. Superior *jooties* and *zari jooties* (gold or silver embroidered) are made mostly in the Punjab, while ordinary *chappals* are made in Western India and in Calcutta, Madras and Cawnpore. In N. W. F. P., especially at Peshawar, Kohat and Bannu, large quantities of *Peshawari chappals* are made for local use and also for export to the Punjab.

For *mundas* and other coarser types of foot-wear generally bag-tanned buffalo leather is used for the upper and the sole, and for better grades, bag-tanned cow leather is used for the upper. Superior types of *chappals* are made from chrome leather uppers. In the manufacture of *mundas*, *nagras*, and *zari jooties*, cut uppers after closing and beading, are stitched to the sole with thread or leather. No lasts are employed.



CHAPPAL

Chappals consist essentially of a sole and a number of straps for uppers. With very few exceptions, uppers are always straps of various shape and width, and they are arranged to provide a firm grip around the instep and the big toe. In *chappal* making, bottoms and uppers are prepared separately.

PESHAWARI CHAPPAL

and uppers are attached to the sole by stitching, nailing or riveting. The *Peshawari chappal*, which is being increasingly used, is made from a separate insole, sole and heel, two vamps, two quarters and one back strap, and is fitted with buckles for fastening.

Embroidered slippers are known as *zari jooties*. The manufacture of these artistic foot-wear developed in India during the Mohammedan period, mainly in Agra and Delhi. Gold and silver threaded shoes, with rich ornamentations on them, are at present manufactured in Delhi, the Punjab (especially in Jhelum dist.), the U. P., the C. P., Jaipur, Sind, and Calcutta. The making of these shoes is a fine art. The uppers are cut and patterns marked on them by men. Embroidery is done mainly by women. There are innumerable shapes, varieties and designs, but considering the high qualities of embroidery on these shoes, the leather used is often of inferior grade.

PRODUCTION, IMPORTS, & EXPORTS

In pre-war years, India produced annually about 70 million pairs of indigenous types of foot-wear and 16.8 million pairs of Western types of foot-wear (Rep. Marketing Hides India and Burma, 1943, 90). During World War II, the output was 140 million and 30 million pairs per annum, respectively. During the War, the number of workers in the shoe trade nearly doubled. Messrs. Cooper, Allen & Co. increased their labour force from 3,000 to 10,750, and Batas, from 3,600 to 7,550. But production increased only to about 21 per cent. Much of the extra labour was employed for the preparation of subsidiary articles and materials required for making Service foot-wear. Further, several mechanical operations had to be performed by hand.

Production of Service foot-wear increased at a tremendous rate and a large number of new types were designed and manufactured. These included women's Service foot-wear, specialized foot-wear for Air and Naval Services and for jungle warfare. The most important tasks in developing Service foot-wear were the skilful selection of components from available materials, and the developing of substitutes for materials in short supply. Amongst the latter, reclaimed rubber for rubber-soled shoes, replacement of rubber soles by jute soles, rubberised canvas legs in place of rubber legs in knee or gum boots, are worth mentioning. Shortage of heavy sole leather was overcome by the introduction of laminate half soles, and other repair components (*vide* also Minist. Supply, Lond., A Study of Substitutes for Leather, 1946). There was also an acute shortage of grindery, and this was overcome by altering the design of the 'make.'

As a result of the increased demand for the Forces, drastic cuts had to be made in the civilian market, where acute shortage prevailed throughout the War. During the War, prices of foot-wear began to rise rapidly with increase in the prices of raw materials, and this tendency was greatly checked by control.

Out of the 26 million pairs of leather foot-wear supplied to the Army during the total period of the War, more than 20 million pairs were supplied by Cooper, Allen & Co., and 2.5 million pairs, by Bata Shoe Co. These consisted of 16.39 million pairs of ankle boots, 1.52 million pairs of black leather shoes for Naval and Air Forces, 5.31 million pairs of *Peshawari chappals*, and 0.56 million pairs of sandals. Of the 36 million pairs of rubber and canvas shoes supplied to the Army during the War, Batas supplied about 29.5 million pairs including 26.2 million pairs of plimsolls.

Pre-war production of leather foot-wear was sufficient for distribution at the rate of one pair per five persons. With increase in the standard of living, the potential demand may be put at a minimum of 400 million pairs per annum. The total supplies of hides and skins available in India every year, even if solely used for the production of leather foot-wear, will not be sufficient for more than 200 million pairs.

ANNUAL PRODUCTION OF HIDES AND SKINS IN INDIA*

	Million pieces
Buff hides	5·7
Kips	20.0
Goat skins	27·5
Sheep skins	17.0

* Rep. Marketing Hides India & Burma, *loc. cit.*; Rep. Marketing Skins India & Burma, 1943.

PRE-WAR PRODUCTION OF LEATHER FOOT-WEAR IN INDIA*

	Leather used (Million pieces)	Skins used (Million pieces)	Foot-wea (Million pairs)
Country types ..	8.75	2.0	70.0
Western types ..	2.10	2.1	16.8

* Rep. Marketing Hides India & Burma, *loc. cit.*; Rep. Marketing Skins India & Burma, 1943.

AVERAGE ANNUAL IMPORTS OF BOOTS AND SHOES INTO INDIA

Qty. (in thousands pairs) and val. (in thousand rupees)

	All leather		Rubber soled, canvas upper		Rubber soled, other uppers		All rubber		Other materials		Total	
	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.
In quinquennium ending—												
'33-34	344	1436	5318	3635	..	..	..	..	2811	1171	8473	6801
'38-39	420	1269	1373	869	46	46	250	131	87	137	2175	2452
'43-44	76	280	36	33	13	15	10	19	25	45	160	292
In '44-45	1	14	1	1	..	..	..	..	..	1	2	16
,, '45-46	5	68	..	..	..	..	3	9	2	14	10	91

In '38-39 the different types of boots and shoes imported into India were : all-leather, 25·4 ; rubber soled with canvas upper, 37·9 ; rubber soled with uppers of leather or other materials, 1.5 ; all-rubber, 2.8 ; and of other materials, 5·5 per cent.

BOOTS AND SHOES

IMPORTS FROM PRINCIPAL SUPPLYING COUNTRIES IN '38-39

(In per cent.)

Type	Japan	U. K.	Czecho-slovakia
All-leather	..	13	77
Rubber soled, with canvas uppers	57	..	40
Rubber soled, with uppers of leather or other materials ..	..	8	85
All-rubber	34	19	14
Other materials	8	13	53
All varieties	23	9	60

Japan was the chief supplier of plimsolls, and Czechoslovakia, of all-leather and other types of shoes.

Imports of boots and shoes are subject to a revenue duty of 25 per cent. *ad valorem* or six annas per pair, whichever is higher, *plus* 1/5 of the total duty. Uppers for boots and shoes, unless entirely made of leather, are subject to a duty of 25 per cent. *ad valorem*, or three annas per pair, whichever is higher, *plus* 1/5 of the total duty.

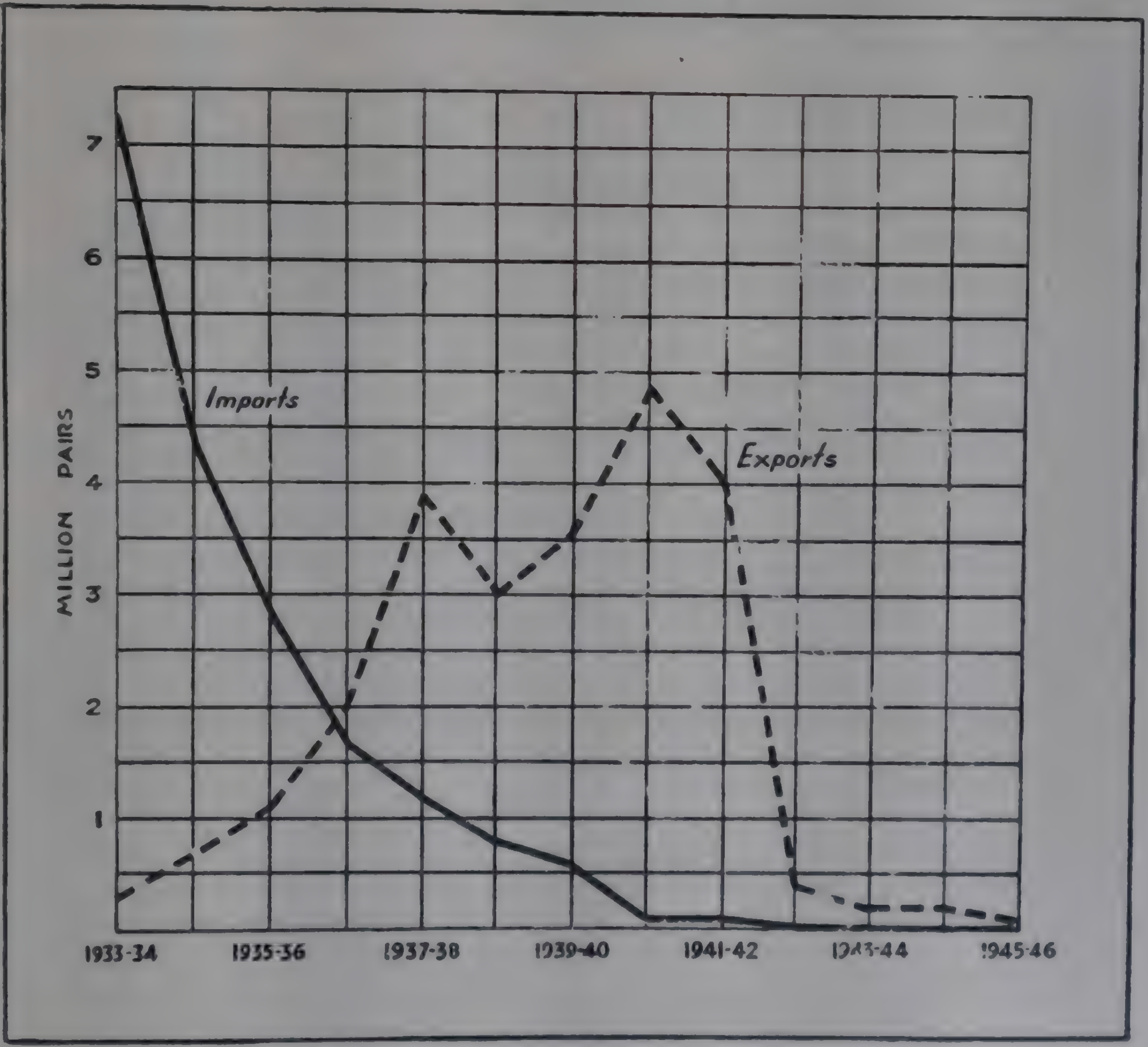
AVERAGE ANNUAL EXPORTS OE BOOTS AND SHOES FROM INDIA*

Qty. (in thousand pairs) and val. (in thousard rupees)

In quinquennium ending :	Rubber soled, canvas upper		Other materials		Total	
	Qty.	Val.	Qty.	Val.	Qty.	Val.
'33-34 ..	..	..	..	..	217	348
'38-39* ..	..	..	..	..	2,119	1,582
'43-44 ..	1,866	1,379	767	1,501	2,633	2,880
In '44-45 ..	1	5	162	1,011	163	1,017
,, '45-46 ..	..	..	107	516	107	516

* Exports of rubber soled canvas shoes have been recorded separately from '36-37.

Exports of Indian boots and shoes showed a marked increase after '33-34 and reached a peak of 4.9 million in '40-41. Exports in '38-39 consisted principally of plimsolls (69 per cent.), to Portuguese East Africa, British West Indies excluding Bahamas, and Burma, each country taking about 25 per cent. of the total exports of plimsolls. Burma was the chief market for other varieties of Indian boots and shoes (68 per cent.).



IMPORTS & EXPORTS OF SHOES

BRASS AND BRONZE WARE

The making of brassware is mostly a cottage industry spread throughout India, large mechanised factories being found in a few places like Bombay and Poona. In recent years, owing to increasing popularity of aluminium, enamelled iron, and porcelain vessels, the demand for brass and bell-metal ware is showing a slight decline.

Bengal has a widespread brass and bell-metal ware industry. Important centres for brassware are Dhamarai (Dacca), Palong (Faridpur), Matiari (Nadia), and Dainhat (Burdwan) ; and for bell-metal ware Dhamarai (Dacca), Nawabjung and Araipur (Malda), Khagra (Murshidabad), Sadhanpara and Sarak (Nadia), Karar (Midnapore), and Vishnupur (Bankura). Vishnupur also produces German silver articles. During 1939, production of brassware was 75,000 md., valued at Rs. 22 lakhs and of bell-metal ware, 51,000 md., valued at Rs. 32 lakhs (Rep. Surv. Brass & Bell-metal Industr. Bengal, 1939, 5).

In Bombay province the industry is widely distributed, the most important centres being Bombay, Poona, Nasik, Hubli and Pardi (Surat dist.). Large factories in Bombay and Poona manufacture tiffin carriers, buckets, cups, saucers, *lotas* (tumblers), *thalis* (plates), cooking utensils, etc.

In the U. P., the chief centres of brassware production are Moradabad, Hathras, Mirzapur and Benares. Excepting *thalis*, trays, tea-sets, etc., which are made from sheets, almost all the other articles are made from scrap.

Moradabad is famous for utensils and artware. About 60 per cent. of production consists of utensils ; 30 per cent. of ornamental brassware ; and 10 per cent. of E. P. N. S. ware, and cutlery. Further, brass utensils, imported mostly from Bombay and Poona, are here polished and tinned, or nickel-plated, for sale as Moradabad ware. The artware consists of ornamental castings, such as, engraved and lacquered *pan-dans* (boxes for betel leaves and nuts), flower vases, trays, *thalis*, cigarette cases, ash trays, etc. During '45, ornamental brassware worth about Rs. 50 lakhs was manufactured and a fair amount was exported to America.

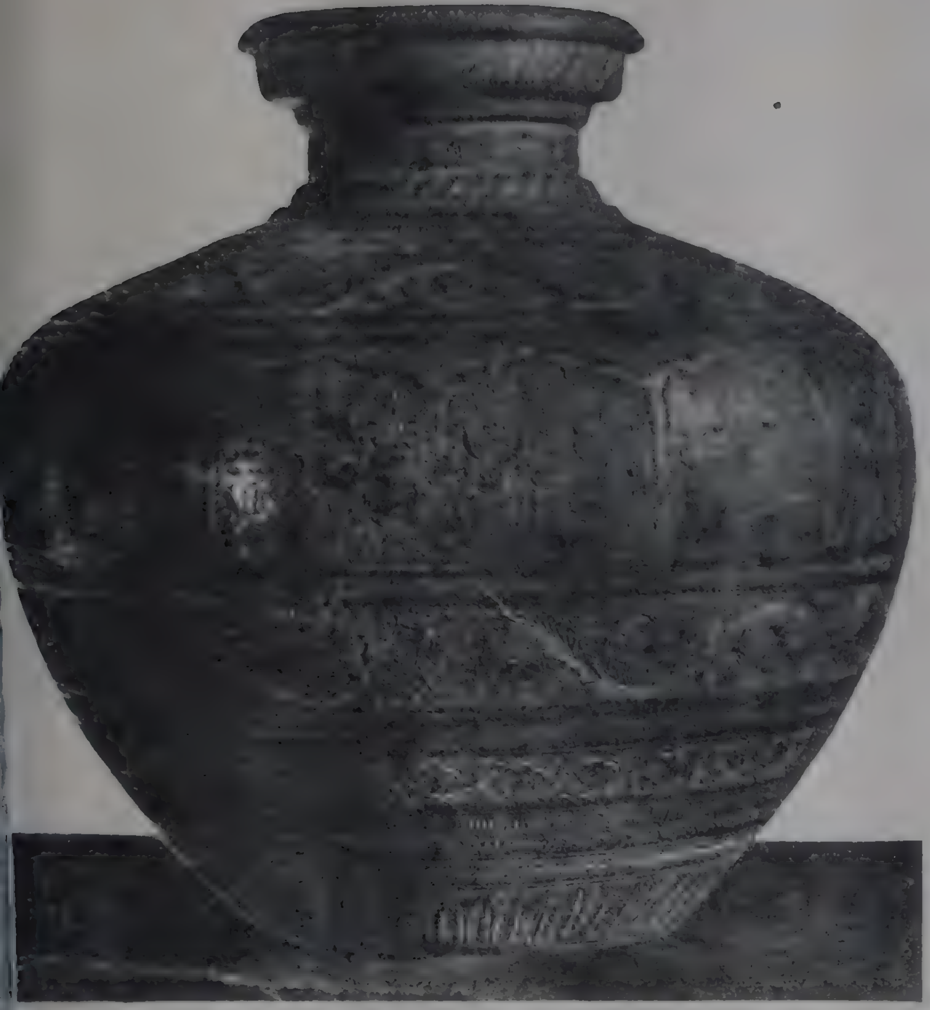
Benares has specialized in line and repousse work on sheet and hollow brassware, and at one time had an overseas market, but trade is declining. Brass artware is made entirely from imported sheets, while scrap is utilized for domestic utensils.

In Madras, Chittoor (Tirupati), North Arcot (Vellore), Trichinopoly (Lalgudi), Tanjore (Kumbakonam) and Madura dists. are well-known for brassware, and Chitoor (Kalahasti), Madura (Dindigul) and Malabar dists. for bell-metal ware.

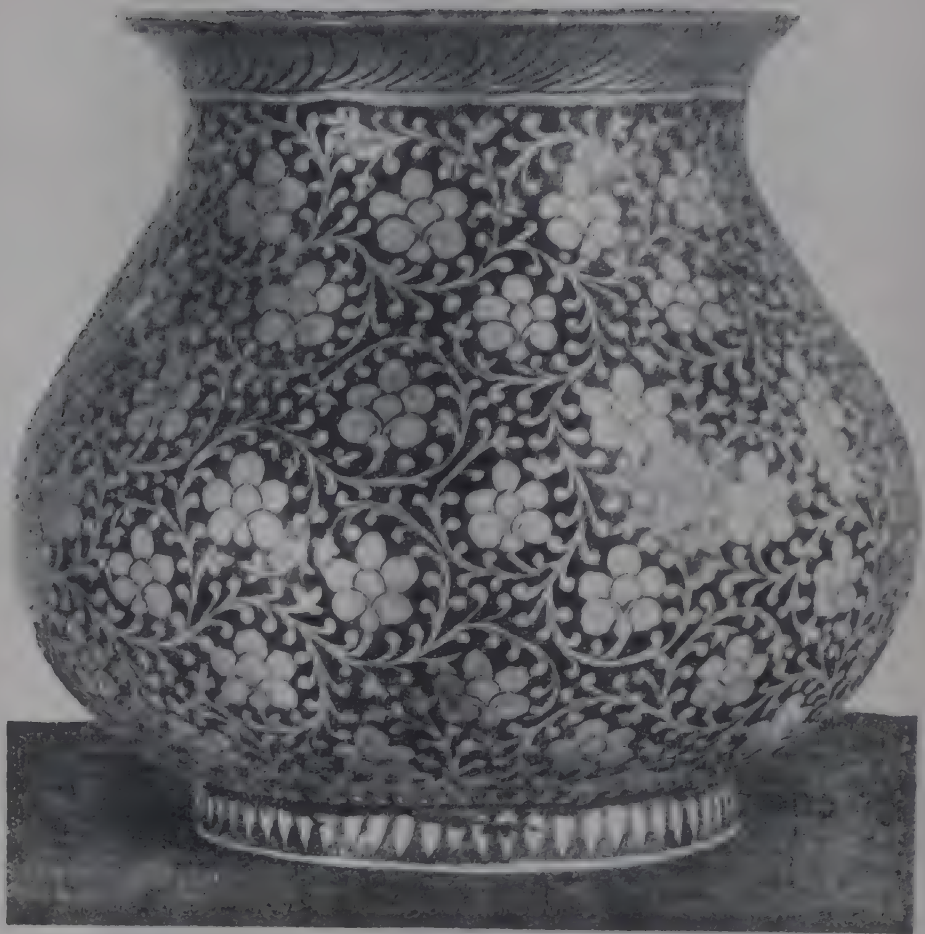
Delhi has a fairly good brassware industry of the Moradabad type. In certain factories, the articles are machine finished, tinned or electroplated.

Among the States, Jaipur and Porbandar are famous for high quality brassware. Jaipur is especially noted for its artware made mainly from brass sheets, comprising trays with arabesque designs from Indian patterns, engraved vases, repousse' work, etc. Baroda and Kashmir also produce repousse' articles. Brassware is also made in Mysore, but the finish is not good.

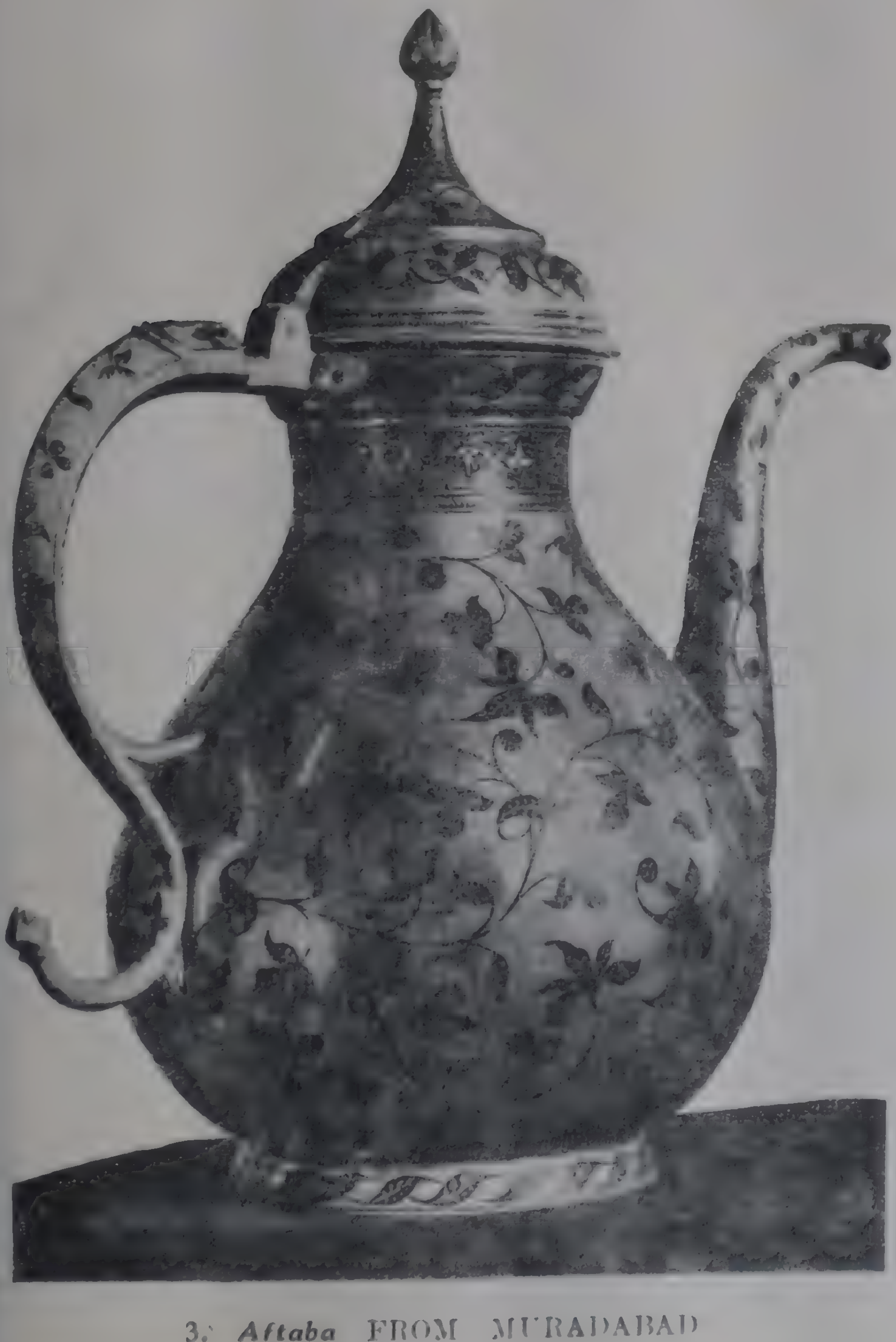
Until recently, Indian brassware industry depended solely on imported brass sheets, and on scrap. The use of old and broken articles entails additional labour as they have to be melted to prepare ingots. There are now a number of small rolling mills distributed throughout India, and bigger brassware manufacturers prepare their own sheets and strips. Brass sheet of very good quality is manufactured by the Indian Copper Corpn. at Singhbhum. In 1947,



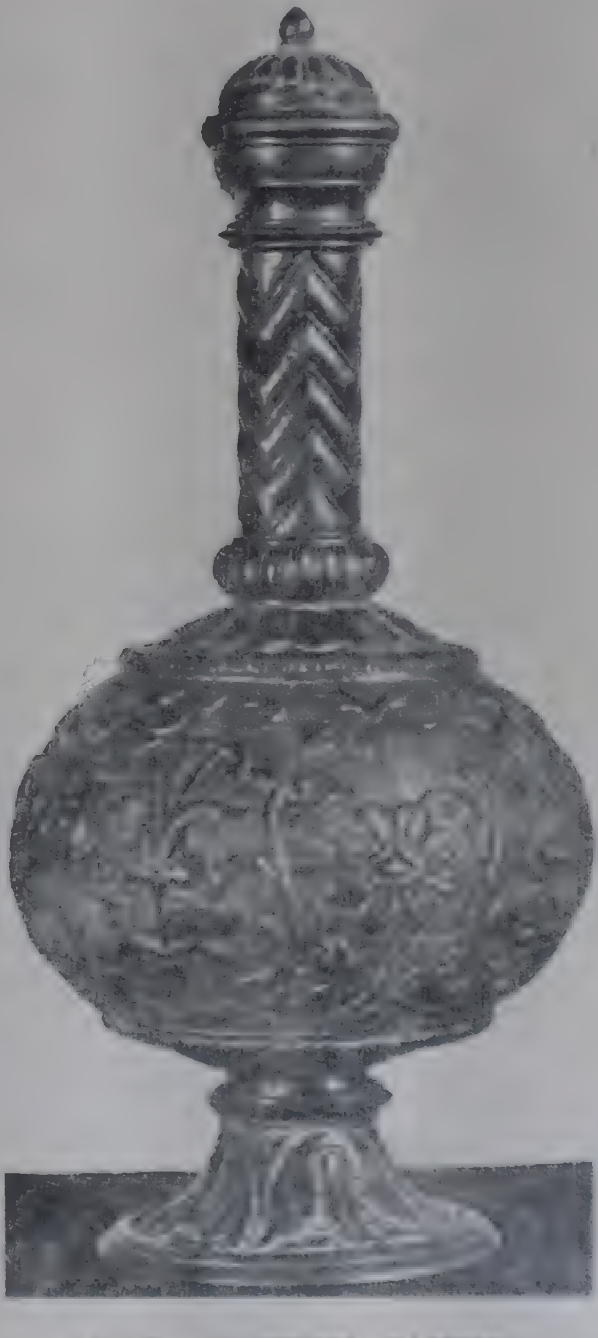
1. WATER-POT FROM BENARES



2 MURADABAD *Lota*



3. *Aftaba* FROM MURADABAD



4. *Surahi* FROM JAIPUR

the industry consumed 30,000 tons of brass sheets, and it is estimated that hereafter the average annual consumption will be *ca.* 40,000 tons.

Bell-metal (Cu, 7 ; Sn, 2) is a wellknown alloy of the bronze type. It is mostly obtained by melting down broken vessels. In Bengal, a small proportion (about 10 per cent.) is made directly from copper and tin. Ordinary gun-metal and *bela*, an inferior bronze, are also used.

Bharan, a special kind of gun-metal, is used only in Bengal, especially in Dacca. It is made from brass, copper and zinc, and is usually obtained by melting broken vessels. This alloy is not so malleable as bell-metal or brass, and can be worked only by casting. The articles manufactured from it consist chiefly of tumblers and cups.

Imported German silver sheets are used mainly in Moradabad, and in Vishnupur. *Gulli*, prepared by melting cupro-nickel scrap and zinc, in the ratio of 3 : 1, is used in Moradabad for casting E. P. N. S. ware. *Bharat*, an alloy used in Kashmir, is an inferior bronze made by melting together equal quantities of gun-metal and *bela*.

MANUFACTURE

There are two methods of manufacture of brass and bell-metal ware : the beating process, and the casting process. The former is mostly done by hand, and the operations consist of smelting, forging, hammering and beating out in the cold, scraping, spinning and polishing. It is used for making brass and bell-metal ware from scrap, mainly in Bengal. Scrap is melted in earthen crucibles. The molten metal, after clarification with a little borax and salt, is poured into small earthen pots. The resulting ingots are repeatedly heated and hammered to proper size and shape. The pieces are finally hand-scraped and smoothened in a wooden lathe, and polished by rubbing with jute fibres or coir, smeared with some oil, and mineral acid. Sheets are being increasingly used for making utensils. They are cut into pieces of proper size and shape. These are then successively heated and hammered to shape on an iron anvil. The parts prepared are joined together by soldering, or by brazing with brass. Firmer joints are made by the use of silver in place of brass. Trays, plates, etc. are made from single pieces, and require anvils of different shape. German silver sheets are also treated in the same manner.

Gun-metal and other inferior alloys containing brass, copper and zinc, and which are not so malleable as bell-metal or brass, are usually cast. *Bharan* tumblers and cups also are cast. The cast articles are scraped by means of a chisel, and polished on a lathe.

Two methods of casting are employed. In the first, both the mould and the crucible containing the metal are heated together. In the second, which is more common, the molten metal is poured into the mould. In the case of some vessels, the parts are cast separately and then soldered. The cast articles are then filed to remove surface irregularities, and defective castings are soldered. They are finally scraped by means of chisel on an improvised lathe, and finished.

In mechanical production, brass circles of 20, 21, 22 S. W. G. (Cu, 70 ; Zn, 30) are drawn in stages according to the depth required, followed by spinning operations in one or more steps, as in the case of aluminium ware. Very few articles are spun directly from circles. Deep pressings are made with intermediate annealing. Parts of brass utensils are joined together by riveting or pressing. The surface is then scraped in a lathe, or rough finished with emery paper. This is followed by buff polishing with abrasive soap, or burnishing with a blunt tool which gives the article smoothness and high polish.

When finishing cooking and household

utensils, they are given a rough scrubbing with a mixture of powdered charcoal and tamarind pulp, or with emery paper, followed by further beating with a small, sharp hammer, till the entire surface is covered with facets for ornamental effect. Some articles are finished in lathes, and polished. Thicker vessels, and those in which the inside is not polished, are finished by pickling with nitric acid.

Moradabad articles are given a final coating of pure tin (*qalai* work). In *qalai* work, the vessel is heated in a hearth, and a piece of tin is placed on it. When it melts, sal-ammoniac is sprinkled on it and the molten metal is spread on the surface with a cotton rag. During subsequent heating, the body is completely covered with tin, and the coating is extremely durable. After tinning, the vessel is washed to remove sal-ammoniac and again heated, when the coating hardens. It is finally rubbed with a powder made from fragments of old crucibles, and polished with a mixture of *kurand* (corundum ?) and vegetable oil, and then with wood ash. Owing to high cost of tin, it has been replaced, now, by an alloy containing 1 part of tin and 3 parts of lead, with consequent deterioration in quality and durability. Moradabad ware is also increasingly electroplated with nickel or silver. These finishes, though cheaper, are not so durable.

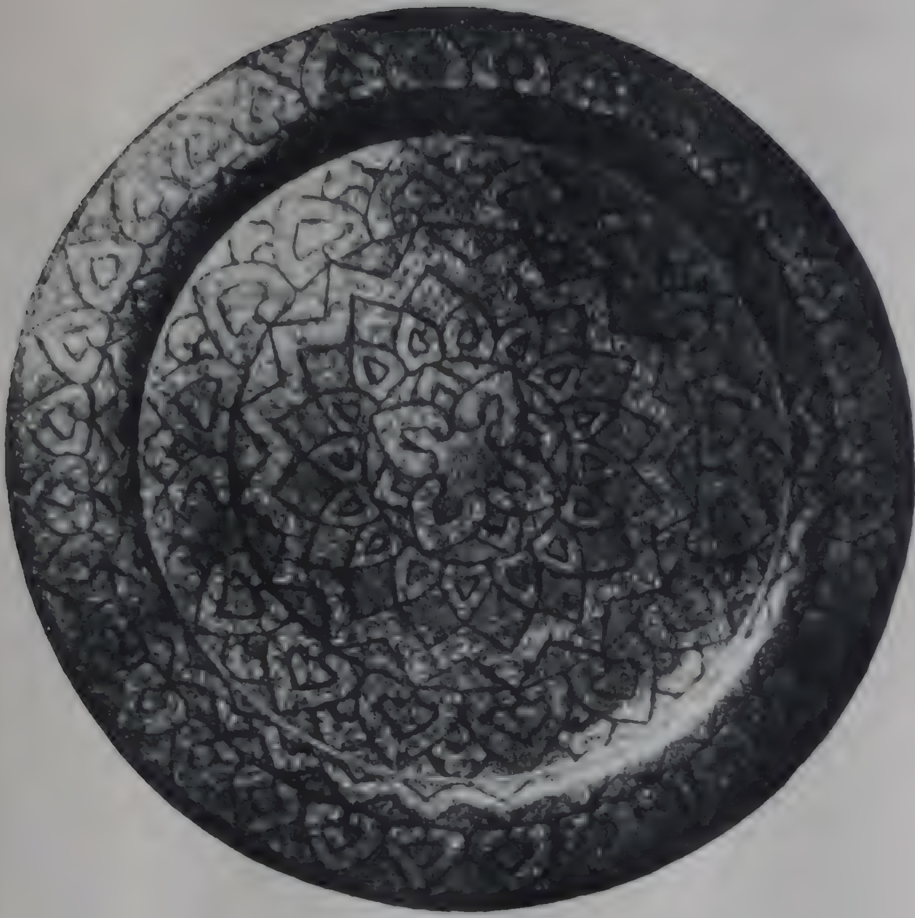
ARTWARE

The chief centres for brass artware are Jaipur, Moradabad and Benares, and the work consists of two types : engraving and embossing. Other important centres for artware are Kashmir, Baroda, Nasik and Poona.

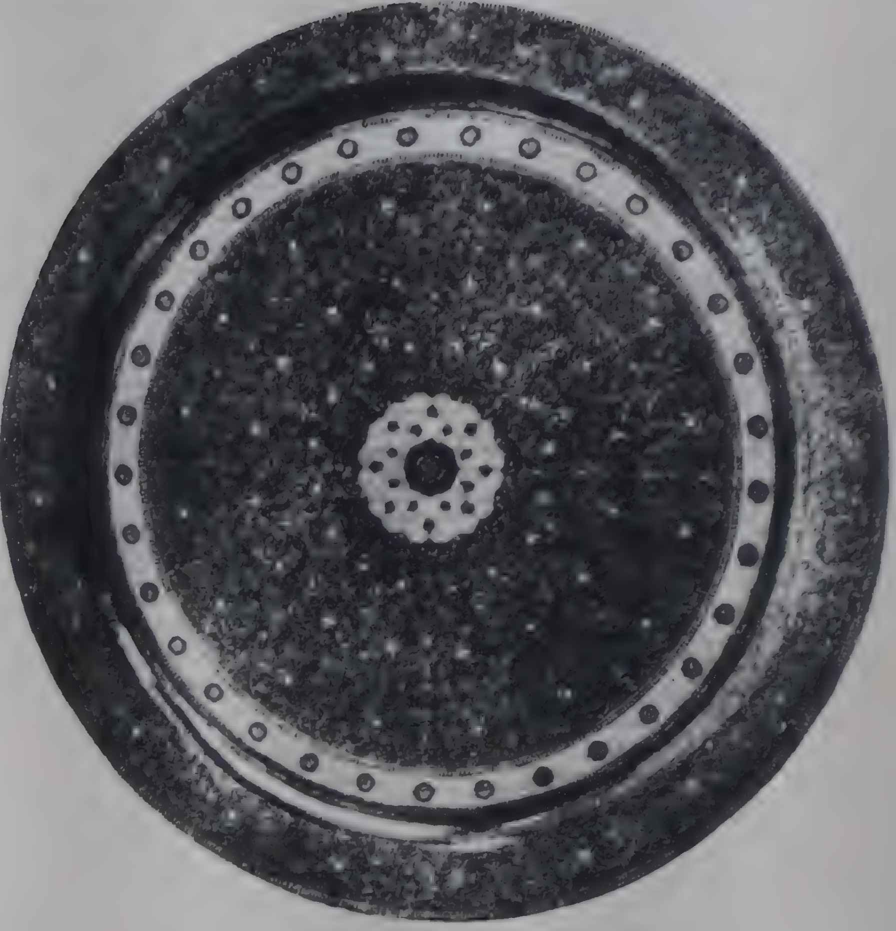
In embossing, the design is brought into relief by hammering. Hollow vessels are filled with hot pitch or a mixture of resin, powdered bricks and vegetable oil, which on cooling forms a hard core. The outline of the design is first chased out, and the ground is gently hammered with small iron punches, resulting in a flat relief of the design. For higher relief, the operation is repeated. Flat articles, such as, *thalis*, trays, etc., are fixed in pitch or gum, and hammered. The pitch is then removed, and the surface polished with tamarind pulp and water, and then with acid. Repousse work is a speciality of Jaipur and Benares. At Jaipur it is often engraved, while at Benares the background may be plain, frosted (*rukha*), engraved, perforated, or cut into *jalis* (screen or lattice work). Baroda and Kashmir also make repousse work.

Engraved brassware is made principally at Moradabad, Jaipur and Benares. The workman, with a small mallet in one hand, and an iron graver in the other, works out figures or conventional designs of flowers, etc., on the article, fixed to a lac blacking. Other designs prevalent are jungle scenes of animals, landscape and imagery. These are generally made from memory, no patterns or tracings being employed. For lacquering, the vessel is warmed and the portions chased out are filled with coloured lac. Excess of lac is scraped off, and the surface polished with *kurand*, oil and wood ash, using felt and cloth.

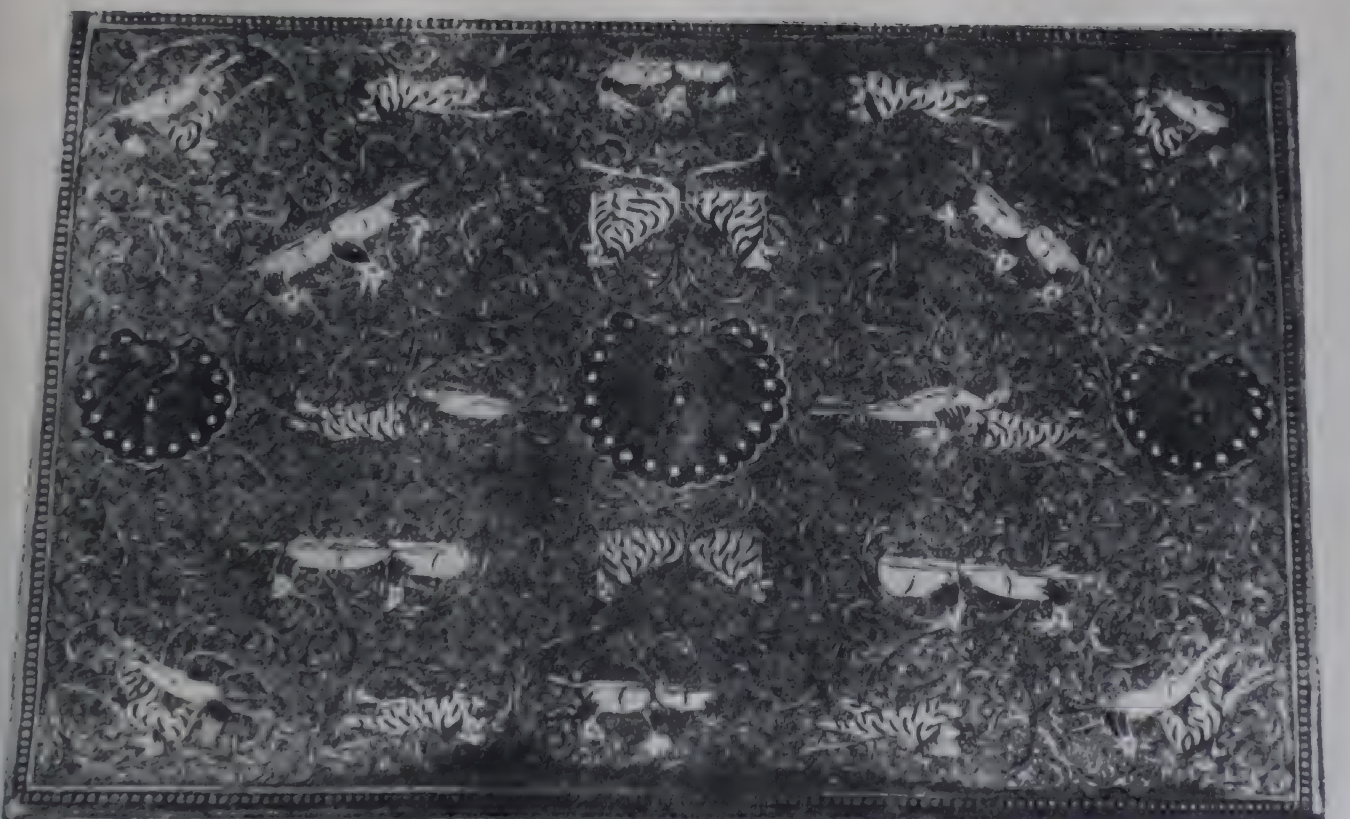
At Jaipur, three styles of engraving are done. They are known as *chikan*, *marori*, and *bidar*. Sometimes engraved and lacquered articles are nickel-plated. In *chikan*, the design, which is usually a bold floral decoration, stands out in relief against the background, which is chased out and filled with lacquer. The flowers also may be slightly engraved. *Marori* is very much finer work, in which the background is covered wth minute lacquered engravings, sometimes circular. In *bidar* work, the entire article is covered with minute leaves and flowers in relief against a chased background, filled with black lacquer. The design is not so delicate as in *marori* work. Occasionally Jaipur engravings are done on silver-plated articles.



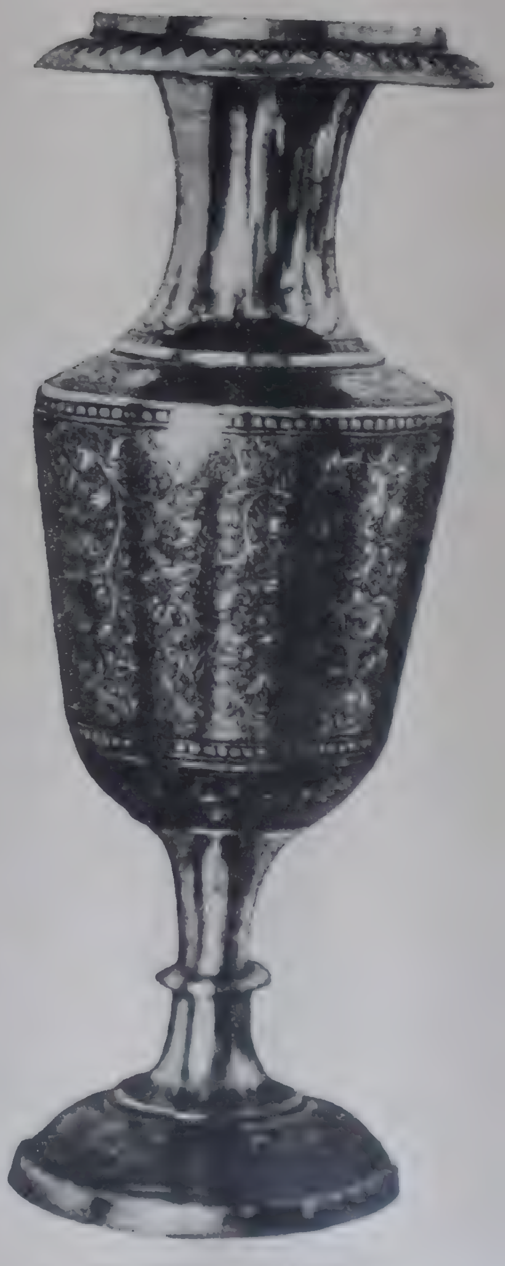
1. PLATE, CHIKAN WORK



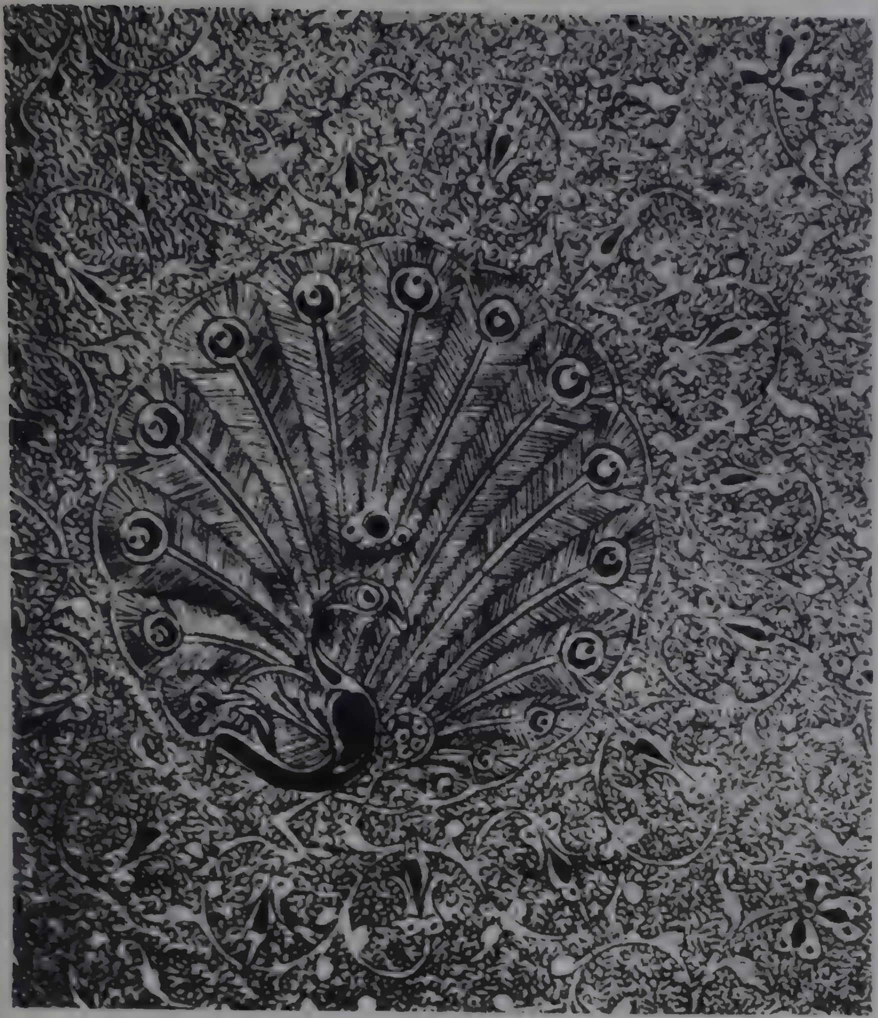
2. PLATE, MARORI WORK



3. CIGARETTE CASE



4. FLOWER VASE



MARORI WORK

Moradabad brass artware generally consists of cast articles. Engravings may be plain, or of *siah qalam* work. In the former, the floral pattern is engraved or incised on a tinned article so that brass shines out against a white background. Sometimes, the inside of the decoration is ornamented with frosted patterns (*sumba*) and indentations (*nok*), by hammering with a steel punch. The engraved articles are finally hand-polished. This type of decoration with incised floral patterns is also engraved on plain brass, and the articles are finally buff polished.

Siah qalam work, similar to *bidar* style, is characteristic of Moradabad. In this, the design is in relief against a chased out background filled with black lacquer (cf. Bidriware). In modern work coloured lacquer is also used for filling the background. As in Jaipur artware, engravings may be of different grades of fineness, *chikan* or *marori*. Sometimes *siah qalam* work is nickel or silver-plated.

Benares engravings are quite different and are not given any lacquering or plating. The outlines of the design are chased and the background is frosted by hammering with a small steel punch containing a frosted design in relief. Now-a-days the entire design is being made by using hammering punches, with different designs.

In Bengal, Khagra (engraved plates and dishes), Ranaghat and Nabadwip in Nadia dist., produce some artware. Brass towers prepared in Palong (Faridpur dist.) are in demand for decorating pagodas in Tibet and Burma.

In the south, the wave of *Saivism* in the 9th century gave rise to a great school of Indian bronzes. Several images of great artistic value, manufactured during this period, are to be seen in many of the south Indian temples, and in the Madras Museum. These images were made of *panchaloham* (five metals), the ingredients being copper, silver, gold, tin and lead. In modern practice, many south Indian images are made only of copper. Even now small idols of Hindu deities are made, especially at Perumalapalle and Tiruchanur, near Tirupati. Bigger idols are rarely cast (Narayanarao, Preliminary Rep. Surv. Cottage Industr. Chittoor Dist., 1929, 25).

The image is first modelled in wax which is wrapped in a thick coating of soft clay, held in position by wires. The wax model is then melted away leaving a ' hollow ' into which the alloy is poured. After the metal has cooled and set, the mud wrapper is removed and the figure is then chased and chiselled. Formerly images were also made at Poona, Nasik, Vizagapatam and in Malabar.

VALUE OF EXPORTS OF INDIAN ARTWARE BRONZE AND BRASSWARE

	Lakhs of Rs.
'37	1.11
'38	1.46
'39	0.79

BRICKS

Bricks are produced in almost all towns and villages in India, and organized brick fields are found in the neighbourhood of large cities. Refractory bricks, a special class of bricks, are included under Refractories (q. v.).

Bricks are made of earth or natural clay, which should be sufficiently plastic, and should not shrink, crack or warp during drying and burning. Iron oxide in the clay is responsible for the characteristic red colour of bricks, and excess of it gives them a bluish black colour. The properties of earth for brick making may be modified by the addition of sand, chalk, etc. Sand prevents cracking, shrinking and warping. Lime in small quantities is essential for fluxing, but is frequently a serious impurity. Too much of it will change the colour to cream or white, and the bricks will crumble to pieces due to slaking. Magnesia also acts as a flux and changes the colour to yellow. Grit and *reh* (alkaline efflorescences from soil) should not be present. The average composition of good brick-earth is : alumina, 25 ; silica, 55; lime, iron oxide, magnesia, etc., 20 per cent.

Three different types of clays are used : (*a*) strong or fat clays, (*b*) loams or sandy clays, (*c*) marls or calcareous clays. Clays of the first type are highly plastic and tough, and are used with small additions of sand or loam. Loam consisting of not more than 25 per cent. of free sand and a small quantity of lime form good brick-earths. Marls also make good bricks, and are generally used alone or with small additions of sand.

For preparing bricks, the clay is mixed with water, and tempered to a homogeneous plastic mass by turning it up repeatedly with shovels, and treading it. In large-scale production tempering is carried out in pug mills. The prepared clay is allowed to dry gradually under cover of mats.

Bricks are made from prepared clay by moulding, pressing or extruding. Sand-moulding is the usual practice in India. In this, a wooden or iron mould is used, slightly larger in size than the finished brick, and which allows for shrinkage in drying and burning. The mould is sprinkled with sand each time before moulding to obtain cleaner and sharper products. A moulder is capable of turning out 600-1,000 bricks per day. Bricks are made by the slop-moulding method in which the mould is dipped in water, from time to time, to prevent clay from adhering to it. The moulded bricks are dried by placing them on their edges side by side, and subsequently stacking them in rows, in the open, for 3-8 days. This makes them sufficiently hard for handling.

A pug mill and an extrusion machine are used in making wire-cut bricks. An improved device for making these bricks is the Auger machine. The pugged clay passes through a pair of expression rollers which forces it through a die, and the extruded clay column is cut transversely into bricks by a series of wires fixed in a frame. Wire-cut bricks are smooth, perfect in form, dense, and of good quality. These bricks require careful drying in order to prevent cracking, and are usually burnt in continuous kilns.

The dried bricks are next burnt in kilns. During burning, the high temperature (875-1015°) of the kiln eliminates chemically combined water from bricks, and causes the oxides present to combine into easily fusible glasses, which bond the material and increase its strength.

Different types of kilns are in use, *viz.*, the Indian clamp or *pazawah*, overground kilns, and underground kilns. The Indian clamp is generally used in villages or small towns for small scale production. It consists of alternate layers of fuel and 4 or 5 rows of bricks arranged on a sloping floor of trapezoidal shape, the proportion of fuel gradually diminishing towards the top. It is ignited at the bottom while it is still being built up, and when completed, is covered with mud for preventing loss of heat. After burning, the bricks are removed, when the kiln cools down. The process is slow requiring 2-6 months. The bricks produced vary greatly in shape, but due to slow cooling they are tougher. The yield of good bricks is about 60 per cent. The initial cost is the lowest and any fuel may be used, but the firing cannot be regulated.

Different varieties of overground kilns are in use, but the best known variety is the Allahabad flame kiln. This is a walled enclosure without roof, generally 44′ long, 18′ wide, and 12′ high (inside). Bricks are stacked in parallel rows with flues for fuel. They are burnt for about 3-4 days, after which all the holes are closed, and the kiln allowed to cool for about 8-10 days.

The Allahabad kiln is more efficient than the Indian clamp, but its initial cost is higher. It allows fire regulation, and the use of comparatively moist bricks. Wood and coal are used as fuel. Some heat is wasted from the top. Cooling is more rapid and the bricks produced are comparatively brittle. The yield is higher and the percentage of superior bricks obtained is about 70.

Underground kiln, such as Bull's trench kiln, is an oval trench dug in the ground, and is widely used for large continuous production. It is cheap and efficient, as waste heat is utilized to warm and dry the bricks prior to burning, and the heating is easily regulated. Bricks are stacked in sections with flues for fuel. Each section, after loading, is covered with mud. Waste heat from a burning section is utilized for the preliminary heating of bricks in the next section. Burning takes about 24 hrs. after which the flue holes are closed, and the burnt bricks are allowed to cool for about 12 days. The yield of superior bricks is as high as 90 per cent., but the bricks are liable to be brittle owing to rapid cooling.

This type of kiln ensures a continuous supply of bricks. While finished bricks are being removed from the rear, those in centre are being burnt, and those in front are being dried. A kiln, about 200′ long, and 15′ wide, produces 5-6 lakhs of bricks in 9 months. Under average conditions in the U. P., about 15 tons of Jharia coal are used for 1 lakh of bricks of 9″ length. The quality of bricks depends on their position in the kiln. 'Body' or 'cherry' bricks, obtained from the interior, are the best.

Burnt bricks are divided into three classes. A brick of the first class is sound, thoroughly burnt without being vitrified and of uniform good colour, shape and size. It is homogeneous in texture, and has sharp edges and parallel faces. When struck, it gives a clear ringing sound, and when immersed in water for 16 hrs., it absorbs not more than one-sixth its weight of water. A brick of the second class is also fairly well-burnt, but is somewhat uneven in shape and is partly vitrified. Under-burnt or over-burnt bricks form the third class. The former are yellowish and soft, and the latter irregular in shape, dark coloured and brittle.

The usual sizes of bricks are : $12'' \times 6'' \times 2\frac{1}{2}''$ (old Indian bricks), $10'' \times 5'' \times 3''$ (usual Bengal bricks), $9\frac{1}{2}'' \times 4\frac{3}{4}'' \times 2\frac{3}{4}''$ (Bengal P. W. D. specif.), $9\frac{3}{4}'' \times 4\frac{3}{4}'' \times 3''$ (Madras P. W. D. specif.), $9'' \times 4\frac{1}{4}'' \times 2\frac{1}{2}''$ (Northern Indian P. W. D. specif.). The width of a brick is about $\frac{1}{4}''$ less than half of its length, so that one brick when laid lengthwise will just cover two bricks laid crosswise, with a filling of mortar between them.

Hollow bricks are light (about 11 per cent. lighter than ordinary bricks) and afford better insulation against sound, heat and cold. They may be made in any brick factory worked by power, and are manufactured in three sizes : 9″ × 4½″ × 3″, 9″ × 5½″ × 2⅝″, and 9″ × 6½″ × 3″. They are mainly used to replace reinforced concrete in roof construction. Roof slabs fabricated on the ground are hoisted into position, saving the costly centering and some cement and steel. The weights of hollow brick roofing, Jack-arch roofing and reinforced concrete roofing are in the ratio : 66 : 100-125 : 70-75.

Ordinary bricks (9″ × 4½″ × 2¾″) cost Rs. 30 ; wire-cut bricks (9″ × 4½″ × 3″), Rs. 100; and hollow bricks, Rs. 120 per thousand (1947). The high prices of the two latter prevent their extensive use.

Paving bricks, bevelled bricks, jamb bricks, arch bricks, etc. are made in special sizes and shapes.

There is a small export of ordinary bricks to Ceylon and Burma. About 66.3 lakhs of bricks worth Rs. 2.2 lakhs were exported during '44-45.

BROMINE AND BROMIDES

Bromine is a dark reddish-brown fuming liquid (sp. gr., 3.19 ; b. p., 59°), slightly soluble in water (3.2 g. in 100 g./20°), but more soluble in chloroform, ether and alcohol. It resembles chlorine in its chemical properties, and is a powerful disinfectant. Liquid bromine causes severe burns when it comes into contact with the skin, and its vapours are highly corrosive and poisonous. It attacks organic matter and may sometimes cause fires. It is stored in glass or earthenware bottles.

In cases of bromine poisoning, milk, white of egg, or starch mucilage should be administered.

The largest use of bromine now is for the preparation of ethylene bromide for anti-knock petrol, to prevent the deposition of lead in motor cylinders. Bromine is the starting material for the preparation of bromides, used in medicine, and photography. It is also used in the preparation of some dyes and drugs. When mixed with kieselguhr, it yields a solid disinfectant Bromine is a constituent of certain poison gases and tear gases.

The chief sources of bromine are sea-water, brines and bitterns, and the natural deposits of potassium salts. In these, it is present in very small quantities in the combined state. Sea-water contains 66 parts per million (0.0066 per cent.) of bromine, and in '33, the Dow Chemical Co. (U. S. A.) developed a process for its recovery (*Industr. Engng. Chem.*, 1936, **26,** 361). Large quantities of bromine are now being produced both from the sea and from the salt lakes. The U. S. A. is now the world's largest producer (102 million lb. in '44), and uses the entire output for the manufacture of ethylene bromide.

The other prominent bromine-producing countries are Germany, France and Palestine, and the production of each was over 1 million pounds in '38. In Germany and France, bromine is recovered from mother liquors left after the extraction of potassium salts from potash deposits (Stassfurt and Alsace). These contain about 0.25 per cent. of bromine in the form of magnesium bromide. In Palestine, bromine is prepared from bitterns (Br, 1.4 per cent.) left after the separation of common salt and potassium chloride from the Dead Sea (Armstrong & Miall, 81).

In the Dow process, chlorine is used to displace bromine from the bromides in sea-water. This bromine is blown out of solution by a current of air and absorbed in a solution of soda ash :

$$3Na_2CO_3 + 3Br_2 = 5\,NaBr + NaBrO_3 + 3CO_2.$$

The bromide-bromate liquor is then treated with sulphuric acid and the liberated bromine is separated by steam, and condensed to yield pure liquid bromine. In the case of bitterns, they are pre-heated and sprayed from the top of a specially designed granite tower, in which they come into intimate contact with a counter-current of chlorine. Steam is blown from the bottom of the tower, and the displaced bromine passes along with the exit vapours at the top and is condensed into liquid bromine in tantalum lined coils or stoneware coils. Uncondensed vapours are absorbed in a column containing iron filings, forming ferroso-ferric bromide, Fe_3Br_8

The bromine obtained contains small amounts of dissolved and combined chlorine, and is rectified in special earthenware columns. It is washed with conc. sulphuric acid and subsequently with water, to yield chemically pure bromine.

The chief difficulty in the manufacture of bromine is the highly corrosive nature of the element, which necessitates the use of inactive materials like stoneware, glass, etc. for plant construction. Tantalum condensers are sometimes employed, but not generally on account of their cost.

Messrs. Tata Chemicals, in '43, began the production of bromine from conc. bitterns (35°Be'.) obtained at their salt works at Okhamandal, with a plant capacity, 1,100 lb. of bromine per day (*J. sci. industr. Res.*, 1946, **5**, 214). During the recovery of salts from bitterns, immediately after the separation of Epsom salt, the residual liquor is processed for the recovery of bromine (yield, 45 lb. of bromine from 1,000 gal. of bittern of 35°Be'.). The plant is operated only during the dry season, and most of the bromine produced is converted into potassium bromide, there being very little demand in India for elementary bromine.

The Pioneer Magnesia Works have recently erected a small plant of capacity 100 lb. per day to recover bromine from Kharagoda bitterns, which contains 0.35-0.50 per cent. of bromine (Kane and Mata Prasad, *J. sci. industr. Res.*, 1943, **1**, 102 ; *vide* also Thorpe, II 108).

BROMIDES

The bromides are salts of hydrobromic acid, which is formed when hydrogen and bromine vapours are passed over heated platinum or by the action of bromine on moist red phosphorus :

$$P + Br_3 + 3H_2O = H_3PO_3 + 3HBr .$$

The bromides of potassium and sodium are used in medicine as sedatives, and in photography. They occur either as colourless crystals or crystalline powders, readily soluble in water. The solutions have a strong saline taste. Sodium bromide readily absorbs moisture from the air, while potassium bromide is only slightly hygroscopic.

These bromides are prepared by treating an aqueous solution of iron bromide with the requisite quantity of alkali carbonate. After filtering off the precipitated iron carbonate, the salts are recovered from solution and purified by recrystallization. Potassium bromide is also prepared by adding a slight excess of bromine to a hot conc. solution of hydroxide, when a mixture of bromide and bromate is formed. The solution is evaporated to dryness, and the residue is mixed with charcoal and heated to redness, to reduce the bromate to bromide. On cooling, the salt is extracted with water and recrystallized.

Potassium bromide of B.P. quality (KBr, 99 per cent.) is being produced by Messrs. Tata Chemicals, and the annual consumption of bromides in India is estimated at 150 tons.

IMPORTS OF BROMINE AND ITS COMPOUNDS INTO INDIA

	Bromides from the U. K.*		Bromine, bromides and bromates from the U. S. A.†	
	Cwt.	£	Cwt.	$
'40	942	10,914	..	..
'41	316	4,511	2,029	59,627
'42	886	14,057	n. a.	n. a.
43	37	786	134	4,992
'44	138	3,162	6	256
'45	317	5,690	n. a.	n. a.

* *Tr. U. K., III;* † *For. Comm. and Navig. U. S.*

BRUSHES AND BROOMS

Brushes were being manufactured in India on a small scale before the last War. The industry is localized in Cawnpore, Bareilly and Agra in the U. P., the chief supply centres for bristles. The largest factory is that of Messrs. Brushware Ltd., Cawnpore, which turns out the major portion of brushes manufactured in India. Brush-making concerns are also established in Bombay, Calcutta, Delhi, etc. Bombay factories produce mainly textile brushes. Messrs. Aspinwall & Co. have a factory at Colachal (Travancore) producing fibre brushes. Brush-making is also a cottage industry, but the products are inferior to factory-made brushes and fetch a lower price. Large quantities of home-made brushes were supplied to the army during the War.

A typical brush consists of a wooden 'stock' or 'board' to which the filling material is fixed, with a 'back' covering its upper side. Usually a handle is also provided. The chief raw materials used in brush manufacture are filling materials (*vide infra*) and wood to hold them.

The principal filling materials are bristles, vegetable fibres and wire. The choice depends upon the purpose for which the brush is intended. Indian bristles are extensively used in brush-making, and large quantities are exported to the London market. Among vegetable fibres bassine, coir and kittool are used for making brushes and brooms, generally as substitute for Mexican fibre, bass and whisk. Steel wire for brush-making is imported.

Filling materials	Particulars	Types of brushes
Bristles—		
Dressed	....	Personal brushes (for clothes, hair, shaving, etc.), paint and varnish brushes, sash tools, tar brushes, and certain industrial brushes.
'Shorts'	....	Cheaper brushes.
'Riflings'	....	Button brushes.
'Darjeeling' bristles ..	....	Sash tools.
'China'	Small quantities imported from China.	Flat varnish, and shaving brushes.
Synthetic bristles	Imported. ..	Nail and tool brushes, and some types of industrial brushes.

Filling materials	Particulars	Types of brushes
Hair—		
Horse hair	Tail hair. Lacks strength, toughess and wearing qualities. Generally used in admixture with bristles.	Shoe and leather brushes for the army, banisters and brooms, etc.
Goat hair	Very rough. Obtained from Afghanistan. Indigenous variety too harsh.	Lacquer brushes, brushes for metal and leather trades.
Camel hair	Tail hair of a species of Russian squirrel. Very soft and tough. Also the fine woolly hair from the neck and back of the camel. Kashmir squirrel hair used as substitute during the War.	Water-colour brushes.
Sable hair	Reddish yellow hair from the tail of a Siberian weasel-like animal. It is soft and highly durable.	Artists' brushes.
Badger hair	Long, tough and coarse. It is not much used in India.	Shaving and varnish brushes.
Vegetable fibres—		
Bassine	From the leaf stalk of palmyra palm (*Borassus flabellifer*).	Coarse brushes and brooms. Used as substitute for Bahia bass.
Coir	From the husks of coconuts (*Cocos nucifera*). Coarse and strong.	Brooms and coarse brushes. During the War used in place of Mexican fibre for making scrubbing and white washing brushes, and in place of bristle for sweeping, tar and harness brushes.
Kittool	From the base of the leaf stalks of the Indian Sago palm (*Caryota urens*). Smooth lustrous strands, strong and elastic.	Soft brooms and brushes. Used as substitute for Bahia bass.
Mexican fibre, Istle or Tampico	From *Agava lecheguilla* Torr. and other Mexican agaves. Also from *Yucca australis* Trel. Wears well in water. Used as substitute for bristles. Mixed with Bahia bass or bassine to form 'Union fibre' which has good stiffness.	Wet brushes (white-wash, nail, bath and dog brushes) and brooms. 'Union fibre' for scrubbing brushes.
Piassava or bass	From certain palms of South America and Africa, Bahia bass of Brazil from *Attalea funifera* Mart. Strong and resilient fibre.	Generally for hard brushes, brooms and banisters, drain and cask cleaning brushes.
Whisk (Rice root, Broom root)	Mexican whisk from *Epicampes macroura* Benth. Also from a few other Graminae.	Dandy brushes, banisters, industrial brushes and certain brooms.
Wire—		
Tempered steel wire	During the War M. S. wire flat, 16 × 24 S. W. G., or 18 S. W. G. round used as substitute.	Metal cleaning brushes (foundry, condenser and boiler tube cleaning, scraping paint, etc.).
Brass wire	Round and crimped wire.	Circular wheel and plate cleaning brushes.
Phosphor-bronze wire	....	Scrubbing brushes.

The wood used in brush-making should be of medium hardness; close-textured, free from knots, and not liable to split or crack. For toilet brushes, woods of attractive grain and colour are preferred. *Mitragyna parvifolia* (*kaim*), *Dalbergia latifolia* (rosewood), *Chloroxylon swietenia* (satinwood), and *Diospyros ebenum* (ebony) are good for toilet brushes. *Millingtonia hortensis* (*nim-chambeli*), *Hymenodictyon excelsum* (*kuthan*) and *Cedrus deodara* (deodar) are used for ordinary household brushes and brooms ; and *Mangifera indica* (mango) for road-sweeping and drain-cleaning brushes. *Lannea grandis* (*jhingan*) has been used for army brushes, but is expensive in conversion (Trotter, 1940, 174 ; 1944, 199). Aluminium, silver, ivory, celluloid and plastics are also used as substitutes for wood in making toilet brushes.

Other raw materials required are metallic ferrules, rubber solution and brush-making pitch for cementing, wire for tying the tufts in wire-drawing, nails, screws, pins, and glue for securing the backs of the brushes, flax twine for bridling, and varnish and polish.

Most Indian brushes are hand-made, and are either ' pan-set ' or ' wire-drawn '. The working qualities of a brush depend upon the pattern of holes employed. This may be 'open', 'medium', or ' close.' Bristles for personal brushes are invariably sterilized.

There are three kinds of ' pan-set ' brushes. In some, holes are first drilled into the stock to the required depth and pattern. The filling material is divided into knots, and glued to the holes by means of pitch. The brush is then trimmed, the stock sand-papered and varnished. The most common brushes of this type are bass brooms, hair brooms and banister brushes. In another type, the brush consists of a metal ferrule with the handle at one end, and the filling material at the other. The base of the filling material is tied together, dipped in pitch, spread evenly round the peg at one end of the handle, and tied. The ferrule is then placed in position and clinched. No ferrules are necessary in brushes in which the base of the filling material is tied with copper wire. For 'pan-set' brushes, without pegs in the handles, the filling material after being dipped into pitch is arranged in the ferrule and reinforced by means of pins before it dries hard. Alternatively, the filling material may be inserted into the ferrule first, and the setting composition poured in at the opposite end of the ferrule, and reinforced by pins before it sets. The handle is then inserted into the ferrule, and secured by means of pins.

In wire-drawn brushes (hair brushes, cloth brushes, shoe brushes, scrubbing brushes, etc.), the back consists of two parts, the ' stock ' or ' board,' containing holes for the tufts, and the 'back' which is glued to the outside of the stock. Several holes are bored through the stock to receive the tufts. These holes are of smaller bore after a certain depth. The knot is doubled through a wire loop coming from the smaller end of each hole. It is pulled through the larger end and fixed firmly by tightening the loop. After filling all the holes and trimming the tufts, the back is glued and pinned, and the brush is finished.

Slogging machines are mainly used for making personal brushes. They drill holes of the required depth and pattern into the solid back, push in the knots, and secure them by staples, but there are very few in India. In twisted wire handle brushes, wire of proper gauge is doubled and held between two vices, one of which is free to revolve. The filling is inserted evenly between the wires and the free end is rotated until the filling is fixed in the twists of the wire, and then trimmed.

Brushes of various kinds are manufactured in India. The chief of these are : (*a*) personal brushes, such as shaving, cloth and nail brushes ; (*b*) paint and varnish brushes, sash tools, stencil brushes, tar brushes, and brushes for cleaning metals ; (*c*) commercial brushes ; banisters and brooms, drain cleaning, and scrubbing brushes, brushes for whitewash, bottle cleaning and cask washing; (*d*) miscellaneous brushes, horse brushes, brushes for saddlery, leather, etc. Other varieties, such as tooth brushes, toilet brushes, laquer brushes, and writing brushes are imported. During the War the manufacture of special types, such as writing brushes, and brushes for welding and aluminium soldering sets, was developed in India.

The army is the largest consumer of brushes in India. Next in importance are the railways and certain industries, e.g., textile and leather industries. There was very great expansion in brush manufacture during the War, and large orders were placed by the Government for shaving brushes, boot brushes and hair brushes. Messrs. Brushware Ltd., who manufactured 1.33 lakh of brushes in 37, produced 53.5 lakhs in '42, of which 50 lakhs were for the army. In India, the consumption of raw materials in brush-making in '42, is estimated to have been: bristles, 164 tons; hair, 3.5 tons; fibre, 11.25 tons; wire, 16.5 tons; and wood, 26.111 c.ft. Of these, 1.25 tons of wire and 12 tons of China bristles were imported (Thomas, Rep. Develop. Industr. War Supplies, 1944, 77). After the War, production has shrunk considerably.

In the quinquennium ending '38-39, paint and varnish brushes were imported principally from Germany (46 per cent.) and U. K. (35 per cent.); toilet brushes from Japan (58 per cent.), U. K. (22 per cent.) and Germany (13 per cent.); and other brushes from Japan (60 per cent.), U. K. (20 per cent.), and Germany (15 per cent.). Imports of brooms into India are very small. The trade in brooms was almost entirely between Burma and the Straits Settlements. While many varieties of industrial brushes, and paint and varnish brushes are now manufactured in India, large quantities of toilet brushes, and brushes for special purposes continue to be imported.

ANNUAL IMPORTS OF BRUSHWARE AND BROOMS INTO INDIA

(Qty. and val. in thousands)

	Paint and varnish brushes		Toilet brushes		Other brushes		Brooms		Total	
	Dozs.	Rs.	Dozs.	Rs.	Dozs.	Rs.	Dozs.	Rs.	Dozs.	Rs.
In quinquennium ending—										
'33-34	79	237	279	541	172	373	61	37	591	1,190
'38-39	97	270	358	597	282	516	40	24	777	1,407
'43-44	39	278	176	474	93	359	0.7	6	309	1,117
In '44-45	12	190	185	1,232	25	145	..	0.6	222	1,568
,, '45-46	21	381	197	1,519	25	274	..	0.5	243	2,175

BUTTON INDUSTRY

Buttons are generally made from horns, bones, mother-of-pearl, metal or from synthetic materials like celluloid, casein plastics, etc. In India, no serious attempt to start a button industry was made till 1910, when the *swadeshi* movement led to the starting of the manufacture of mother-of-pearl and horn buttons in Bengal. In recent years, metal buttons (brass, iron, aluminium, etc.), are manufactured on an extensive scale in several provinces.

MOTHER-OF-PEARL BUTTONS

Mother-of-pearl buttons are manufactured mainly in Dacca and Tippera districts in Bengal. This cottage industry gives employment to nearly 3,000 persons. Bengal produces annually about Rs. 8-9 lakhs worth of these buttons (Rep. Button Industr. Bengal, *Dep. Industr., Bengal, Bull.* No. 93, 1940, 3).

For these buttons, mussel shells are collected from river banks and river beds in eastern and northern Bengal. They are cut into pieces 1-1½" square, the edges trimmed and finally rounded off on a grindstone. Holes are then drilled, and the smoothening and polishing are generally left to women and children. Only simple implements like cutting pliers, hand drill, ordinary files and hand driven grind-stone are used. This crude technique leads to lack of uniformity both in size and finish. Indian fresh-water shells are not usually perfectly white like sea-shells used by the Japanese. Hence Indian mother-of-pearl buttons suffer in comparison with those imported from Japan.

HORN BUTTONS

In Bengal, the manufacture of horn buttons which began during the first World War, is concentrated in the City of Dacca and gives employment to about 700 people (Draft Rep. Surv. Horn. Industr. Bengal, 1939).

Buffalo horns obtained mainly from Madras and Assam are used as raw materials. Only simple tools like a saw, a file, a knife and a lathe are used. The solid portion of the horn is chiselled off to give it a cylindrical shape and is attached to an improvised lathe. Buttons are cut out by a chisel, which also gives them a polish, and holes are drilled by a bow-drill. In spite of the crude technique employed, the buttons turned out are fairly uniform and display a good polish.

The price of horn varies considerably depending upon colour and quality. The button industry in Bengal consumes annually about 1,400 md. of buffalo horn worth Rs. 35,000 (1939). It is estimated that Rs. 80,000 worth of horn buttons are produced annually. Dacca horn buttons are exported to other Indian provinces and even to Burma and East Africa.

Horn buttons are manufactured on a small scale in Ratnagiri dist. in Bombay, the buffalo horns being obtained from Karwar, Mangalore, and Bombay.

Buttons are manufactured in a similar manner from bones. Such buttons can compete with cheap imported buttons made from synthetic materials. During the War, the Army also used horn or bone buttons and had to accept nut and coconut shell buttons as substitutes. Two firms in the Punjab, Messrs. Janda Manufacturing Co., Lahore, and International Manufacturing Co., Lahore, produced about 150,000 gross of buttons at the low price of Re. 1 per gross. The shells of Indian coconuts cannot be used for buttons of bigger sizes, and East African nuts were imported for the production of sizes above ½" in diam. (Thomas, Rep. Develop. Industr. War Supplies, 1944, 80).

METAL BUTTONS

Many types of metal buttons are made in India, e.g., tin and aluminium buttons for shirts, galvanized iron buttons for shirts and pants, brass buttons for coats and shirts, spring buttons, shirt studs and links, motor-hood buttons, buttons for purses and leather bags. The industry, established in Hyderabad State about 30 years ago, is concentrated in the city of Hyderabad. Here the factories specialize in the manufacture of ornamental buttons (cuff links, *sherwani* sets, shirt sets, etc.).

Brass sheets are utilized in the manufacture of cheaper types of buttons and German silver for the superior types. They are passed through a cutting machine, cut to proper sizes and the design imprinted. The cavities of the designs are then filled by lacquer colours of different shades. They are finally polished and mounted on cardboard pieces for the market. The erinoid (a casein plastic) is used in the fixing of brass rings. One factory is equipped with plant required for enamelling (Director, Comm. & Industr. Dep., Hyderabad, Deccan, 1944).

Nearly 3,000 men are employed in this industry in Hyderabad, and the value of the annual production of button amounts to approximately Rs. 5,00,000. The following table gives the output in numbers (1937) of two factories working in Hyderabad (Adm. Rep. Comm. & Industr. Dep. Nizam's Dom., 1937).

	Sherwani sets	Shirt sets	Cuff links	*Gulla* buttons	Military stars	Badges
The Deccan Factory ..	28,188	48,662	136,000	4,736	2,000	..
The Hyderabad Button Factory	437,817	..	20,127	143,158	..	2,600

Hyderabad buttons are sold all over India. Before the War started, there was good demand for them in Burma, Ceylon, Africa, etc.

Aluminium buttons are manufactured in Agra, and Ratnagiri. For these aluminium sheets and castings are obtained from Bombay.

In Delhi, buttons are also made from tin, galvanized iron sheets and brass sheets. For ordinary buttons, sheets of 22, 24 and 26 gauges are used and for buttons of heavy quality, 20 gauge sheet. During the War, a number of concerns were started in Delhi and the Punjab for making tin and G. I. buttons which involves only the cutting of thin sheets, pitching, hole making and polishing. A unit of 3 men daily produces 9 great gross, single layer G. I. buttons. There was a large production of G. I. buttons for the use of military personnel, since the Supply Dep. was requiring about 2-3 lakh gross G. I. buttons every month. Double layer tin shirt buttons are made from sheets of 28 and 30 gauges. The manufacture involves 7 stages and a unit of 7 workers can produce 13 great gross buttons daily.

Owing to the high price of press buttons during the War their manufacture was started in '43, and by the beginning of '45, there were 25 establishments working at full pressure in Delhi alone. Owing to the very low quality of these buttons, almost every factory closed down by the middle of June, '45.

Different types of dress buttons of brass, aluminium or German silver, are also made in some of the factories. Cloth buttons are produced on a small scale in Bombay and the U. P. Fancy buttons of conch shells are manufactured in limited quantities in Bengal and Travancore. Ivory buttons are also manufactured to meet the requirements of occasional customers. Small scale production of celluloid buttons has been undertaken in Bengal.

Metal buttons were mostly imported from Germany and Czechoslovakia (42 and 37 per cent., respectively) during the quinquennium ending '38-39. Japan monopolized the Indian market for other sorts of buttons (67.4 per cent. during the same period).

AVERAGE ANNUAL IMPORTS OF BUTTONS INTO INDIA*

(Val. in lakhs of Rs.)

	Metal buttons	Other sorts
In quinquennium ending—		
'33-34	8.43	13.16
'38-39	8.94	13.60
'43-44	2.15	5.49
In '44-45	0.09	2.73
,, '45-46	2.24	10.55

ERRATA

Page	Column	Line	In place of	Read
vii	..	1	p.	pp.
viii	2	3	Shoe-makers	Shoe-making
xii	1	27	pc..	pH
6	1	44	65.9°	55·9°
15	1	39	cataletic	catalytic
25	2	1	Fertilisers	Fertilizers
30	1	25	volatalizes	volatilizes
30	2	36	*Treminalia*	*Terminalia*
31	2	17	subsitutes	substitutes
33	1	22	acriflavin	acriflavine
38	1	5	benzed	benzene
51	1	4	622	611
52	2	10	naptha	naphtha
54	2	24	15	5
56	2	26	necessery	necessary
57	1	15	alochols	alcohols
59	2	2	114	$11\frac{1}{4}$
66	1	16	aluminia	alumina
69	1	37	volatalizes	volatilizes
73	2	10	delete ' hyplen '	
110	1	1	*atropina*	*atropinae*
110	1	23	caffein	caffeine
112	1	2/3	*Cupresus*	*Cupressus*
114	1	13	came	come
120	2	20	1-4 oz.	$\frac{1}{4}$ oz.
136	2	11	barely	barley
140	2	17	u(g)	μ(g)
141	1	6	12..	1.2
142	1	13	their	hair
143	2	37/38	indorts	imports
145	1	45	*Castanoposis*	*Castanopsis*
161	2	25	*Calcyina*	*Calycina*
164	1	8	12	$1^{1}/_{2}$
168	1	16	Nawabjung	Nawabganj
170	2	21	blacking	backing
179	2	3	26.111	26,111

TABLES

Page	Table Column	Line	In place of	Read
4	2	1	2.5	3·5
4	3	5	17·9	27·9
4	5	4	15,5	15·5
4	6	6	0.80	0.89
15	2	4	12,665	12,655
18	3	1	1,22	1,23
25 (colnmn 2)	2	1, 2, 3	=	—
49 (Table 1)	1	4, 5	Insert ' In ' before ' 44-45' and '45-46 '	
74 (column 1)	7	1	129.9	29·9
80	1	6	I. A. C.	A. C. I.
91	2	2	366	356
100 (Table 2)	6	2	23.1	29.1
100 (Table 2)	6	3	30.7	33·7
106 (Table 2)	5	6	1,408,393	1,498,393
144 (Table 1)	3	5	25.68	25.08
166 (column 2, Table 1)	..	..	Foot-wea	Foot-wear

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